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# Status assessment of the Persian leopard in Iran

**We conducted a national survey to evaluate the recent status of the Persian leopard *Panthera pardus saxicolor* in Iran. Leopard presence records were investigated in 204 areas under the auspices of the Department of Environment DoE, i.e. in National Parks NPs, Wildlife Reserves WRs and Protected Areas PAs and elsewhere outside these areas within the leopard's putative range from 2007 to 2011. Questionnaires were sent to DoE provincial and regional offices and we conducted interviews with hunters, local shepherds and villagers to investigate illegal killing and poisoning of leopards. Subsequently, records were classified into two reliability categories of confirmed C1 or probable presence C2. We plotted the most recent Persian leopard distribution map in Iran indicating the reliability of the records. Results show that leopard distribution is interrupted in a vast area covering about 6 provinces in the north-west of Iran, where formerly northern and southern leopard distributions were considerably connected. We therefore hypothesise that leopard distribution in Iran is splitting into a northern and a southern range, with the risk of fragmentation. Almost 70% of the leopard mortalities during the study period resulted from illegal killing and poisoning. While leopard occurrence is strongly related to wild goat *Capra aegagrus* densities, wild goat numbers are correlated with protection level, size and number of years under protection for each protected area. We recommend a number of research and conservation priorities such as field surveys to assess corridors connecting leopard main habitats particularly in the provinces located in the north-west of Iran to improve the current and planned conservation programmes. Further transboundary cooperation among the neighbouring countries is essential to improve the Persian leopard conservation in the region.**

The Persian leopard is the last remaining *Panthera* species in Iran after the extinction of the Asiatic lion *Panthera leo persica* and the Caspian tiger *Panthera tigris virgata*. The leopard has therefore a unique importance for the ecological health of wide areas of natural ecosystems in the country and for the cultural heritage of Iran. The writings of various Persian authors (e.g. Ferdowsi 940–1020 CE, Manuchehri Damghani 1040, Baba Taher 1000-1055, Saadi 1184-1283, Mowlana 1207-1273) frequently referred to the leopard as a symbol of strength, intelligence, bravery, justice and valour for the public and the kings. The Persian leopard has been widely distributed in West, South and Central Asia since the times of the Pleistocene, but became extinct in some areas by the mid-20<sup>th</sup> century (Vereschagin 1959, Khorozyan & Abramov 2007). A drastic decline of the leopard population in the Caucasus in recent times has attracted much attention of local and international scientists and conservationists (Khorozyan et al. 2005, 2010). Today, Iran is thought to be the last stronghold for the Persian leopard with occur-

rences in most neighbouring countries (Kiabi et al. 2002, Khorozyan & Abramov 2007). The Persian leopard is listed in the IUCN Red List of Threatened Species as “Endangered” and it is included in the Appendix I of CITES. In the national Red Data Book of Armenia the Persian leopard is considered as “Critically Endangered” (Khorozyan 2010). In Iran, the leopard has been protected by national wildlife conservation laws since 1999. The principal refuges for leopards in Iran are protected



**Fig. 1.** A female Persian leopard was photo captured in Salook NP, North Khorasan Province, north-eastern Iran while a study on the estimation of leopard population size in the area was undertaken (Photo: Asian Leopard Specialist Society).

areas which are represented by national parks NP, wildlife refuges WR and protected areas PA. Some short-term protection has also been offered by No-Hunting Areas NHA, which are usually designated for a certain period of time, normally 5 years, to forbid hunting and enable wildlife to recover.

In this study we present the results of a national survey which was conducted to assess the present status of the Persian leopard in Iran. We first reviewed prior studies conducted in Iran and supplemented these data with new occurrence records that we collected. Thus, in this article we present original data but also indicate and discuss relative findings from other scientists which we collected during our literature review.

## Material and methods

### *Distribution and status assessment*

We collected data on leopard presence from 2007 to 2011 in 204 protected areas (25 NPs, 39 WRs and 140 PAs) and elsewhere outside these areas within the leopard putative range. We prepared a questionnaire that was sent to provincial DoE offices. Respondents were asked to provide information about leopard presence records, human/livestock-leopard conflicts, preliminary threats and conservation needs. Concurrently, we conducted interviews with hunters, local shepherds and villagers to investigate the illegal killing and poisoning of leopards. Whenever possible, we measured dead/killed individuals and leopards immobilised by DoE staff and collected samples for further genetic studies. Complaints of local people about human and livestock-leopard conflicts were recorded from 2004-2011.

The presence records were divided into two reliability categories: confirmed presence C1 and probable presence C2 as suggested by Moqanaki et al. (2010). C1 comprised records

of unambiguous leopard presence, e.g. naturally died/executed/road killed/injured/sick/trapped individuals and/or their photographs or videos. Skins, skulls, and other body parts were assigned C1 only if their place and time of origin were certainly known. Repeated or single observations and anecdotal records made by DoE staff or rangers constituted the C2 cases. Repeated observations refer to more than one record from the same locality while single observation refers to one record from each location. Human or livestock-leopard conflicts were classified as C2 only if the species concerned was verified to be a leopard by rangers and experts of local DoEs. Leopard historical range in the country was plotted using data presented in Etemad (1985), Ziaie (1996), Kiabi et al. (2002), Sanei (2004, 2007) and unpubl. records of DoE provincial offices. Mapping of leopard presence was done using Arc GIS 9.3.

Annual wildlife count data concerning numbers of the wild goat, wild sheep, goitered gazelle and chinkara was obtained from the main DoE office of each province and transformed into densities (number of individuals/km<sup>2</sup>). These prey species were counted by DoE rangers in 2010-2011 during the autumn-winter time of rutting, when most individuals are clearly visible and less vigilant to humans.

Prey count statistics were collected from 104 protected areas (14 NPs, 16 WRs and 74 PAs) out of the 204 surveyed for leopard presence. Data on the wild boar *Sus scrofa* were not used in this study because it is widely distributed, but seldom detected or reported, and is not a priority species for wildlife counting, so its data is skewed.

*Analysis*

We determined mutual correlation between several variables in the sites under protection by the DoE (i.e. WRs, NPs and PAs). These variables included: (1) recent (i.e. 2011) information about size of the area (ha); (2) IUCN protected area category (www.protectedplanet.net), (3) years under protection (period from the year of establishment to 2011), (4) leopard presence/absence status, (5) abundance of wild goat, wild sheep, goitered gazelle and chinkara (together), and (6) their densities.

We defined "no leopard presence detection", if no confirmed (C1) records were obtained from an area within the past decade. For example, in the mid-1970s in Orumieh NP, Provinces of West Azarbaijan and East Azarbaijan, the leopard was introduced to control the abundant wild sheep population on Kobudan Island, however, its presence has not been detected in the past decades. Therefore, the

leopard status in protected areas of Iran was classified as "1" (present), "0" (no presence detection) and "-" (presence/absence status is unclear, no surveys).

Four areas (Hendurabi WR in Hormozgan Province, Kuh Asiab and Kuh Banan PA in Kerman, Chehel-Pa PA and Mish Dagh PA in Khuzestan) were excluded from statistical analyses because the establishment procedures as protected areas were still pending. Calculation of correlation was done using SPSS Statistics 17.0.

**Taxonomy, morphological features and genetic variation**

The leopard is known to be variable in body morphology, coat patterns and colouration, which reflects its high adaptability to environmental conditions (Khorozyan et al. 2006). Persian leopards inhabit different habitats in Iran and other parts of West, South and Central Asia, and their morphological features are also diverse (Heptner & Sludsky 1972, Kiabi et al. 2002, Khorozyan et al. 2006; Table 1). Earlier, this variability motivated scientists to describe two subspecies in Iran, viz. *P. p. saxicolor* Pocock, 1927 and *P. p. dathei* Zukowsky, 1959. The latest studies investigating craniological patterns and molecular genetics showed that Iran is inhabited only by one subspecies, the Persian leopard *P. p. saxicolor* (Khorozyan et al. 2006, Rozhnov et al. 2011). Farhadinia et al. (2015a) have conducted a study on 25 genetic samples from the leopards in Iran to examine the sequence variation in the mitochondrial NADH-5 gene. Results showed the presence of three closely related haplotypes including one commonly found across Iran, Turkmenistan and south Caucasus as well as two localised haplotypes from southern Zagros and eastern Alborz ranges.

Skins, museum specimens and photographs of more than 102 individuals originating from different parts of Iran showed a distinct variation in coat colouration: e.g. greyish to yellowish in the Golestan Province, dark and greyish in North Khorasan, pale in Lorestan, dark in Semnan, yellow to tawny in Ghazvin and tawny in Sistan and Baluchistan Province (Etemad 1985, Sanei 2007, A. Sanei pers. obs. 2002-2011; Fig. 1). Even though melanistic leopards (panthers) have not been confirmed so far in Iran and in other parts of the Middle East, local people and rangers claimed the presence of a black individual in the vicinity of Tandureh NP, Razavi Khorasan Province (Sanei 2007). Furthermore, local vil-

**Table 1.** Morphometric data of adult leopards in Iran.

Parameter	Mean	Max.	Min.	Sample size (n)
Total length, cm <sup>1</sup>	232	332	172	12
Length of tail, cm	90	104	80	13
Height at the shoulder, cm	69	79	58	14
Girth of the chest, cm	77	90	56	7
Body weight, kg	58	78	35	9
Greatest length of skull, mm <sup>2</sup>	248	288	210	21
Zygomatic width of skull, mm	162	191	143	15

<sup>1</sup>Head and body measurements were taken by staff of the Department of Environment and A. Sanei using the curve method in immobilised or freshly dead individuals. <sup>2</sup>Sources of skull measurements: Etemad (1985), Moradi (1999), Kiabi et al. (2002) and Sanei (2007). Two cubs about 4 months old were also measured: body length 93 cm and 101 cm, tail length 37 cm and 56 cm. Body weight for the second cub was 12 kg. Greatest length of a skull, condylobasal length, zygomatic width, length of upper tooth row were respectively 262.4, 232.6, 167.5 and 97.2 mm in a skull from Gorgan in Golestan Province and 210, 195, 134 and 81.3 in a skull from Kerman Province.

**Table 2.** Leopard presence areas recorded from 2007 to 2011 in Iran.

	Presence records (repeated and single records) <sup>1</sup>	Protected areas with presence records	Non-protected sites with presence records
C1 records	141	30	55
C2 records	413	35	233
<b>Total</b>	<b>554</b>	<b>65</b>	<b>288</b>

<sup>1</sup>Repeated records refer to the leopard occurrences registered from the same locality or close locations. Single records refer to a leopard occurrence registered from an area.

lagers reported that a black leopard was observed in 2008 in Garmsar, Semnan Province (Esfandiari, pers. comm.).

### Distribution

#### Historical distribution

Blanford (1876), Birulya (1912) and Pocock (1930) described the leopard as common in the mountains and hills of Persia. Later, Zulkowsky (1964), Lay (1967) and Harrington & Darreshuri (1977) also considered the leopard as a common species occurring in almost all ecosystems of Iran, except in vast plains and agricultural lands. Misonne (1959) and Joslin (1990) wrote that the leopard is particularly common in the Alborz Mts. running from north-west to north-east of Iran where it was reported to feed mainly on the abundant wild boars not hunted by Muslims. Ziaie (1996) indicated the leopard range in Iran to cover almost all the territory of the country, except for a small area in the south-west. According to Zulkowsky (1959), until the late 1950s leopards shipped to the zoos of Germany and France had been captured in the Alborz Mts., particularly near the town of Astarabad (today's Gorgan), as well as in the Kopet Dagh Mts. to the north of Mashhad city. Overall, reports from the last decades indicate that the distribution of the Persian leopard in Iran has always been particularly conformed to two mountainous ranges: the Alborz and the Zagros Mts running from north-west to the south. However, two main deserts of Lout and Kavir located in the centre of the country have been two natural barriers separating local leopard populations in north from those in the south.

#### Recent distribution (post 2000) and habitat preferences

Since 2002, Sanei (2004, 2007) documented leopard presence through countrywide compilation of mortality records (individuals poisoned/executed/shot, killed on roads or found dead), human or livestock-leopard conflicts, questionnaire surveys, interviews with DoE rangers and local villagers, sign surveys, photographs and observations made by experts and knowledgeable local people, museum collections and individuals in captivity. A total of 74 protected and non-protected areas out of 90 areas investigated were found being occupied by leopards, of which 69% are located in northern Iran (Sanei & Zakaria 2011a). These studies refer to the years prior to 2006 and suggested that almost 55% of all areas, where

## *Panthera pardus saxicolor*

### Names:

پلنگ Palang  
Persian leopard

### Head and body length:

137 cm (mean n = 20)

### Tail length:

90 cm (mean n = 13)

### Weight:

58 kg (mean n = 9)

### Global Population:

<871-1,290

### Iranian Population:

550-850 (update required)

### Distribution in Iran:

Along Zagros and Alborz mountainous ranges, Kopet Dagh, mountainous habitats in south, east and central Iran

### IUCN Red List:

Endangered (2016)

### CITES:

Appendix I

### Iran environmental conservation laws & regulations:

Protected species

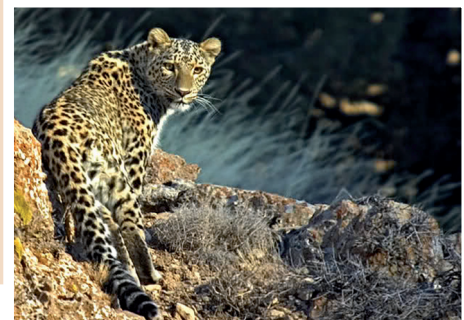


Photo S. B. Mousavi

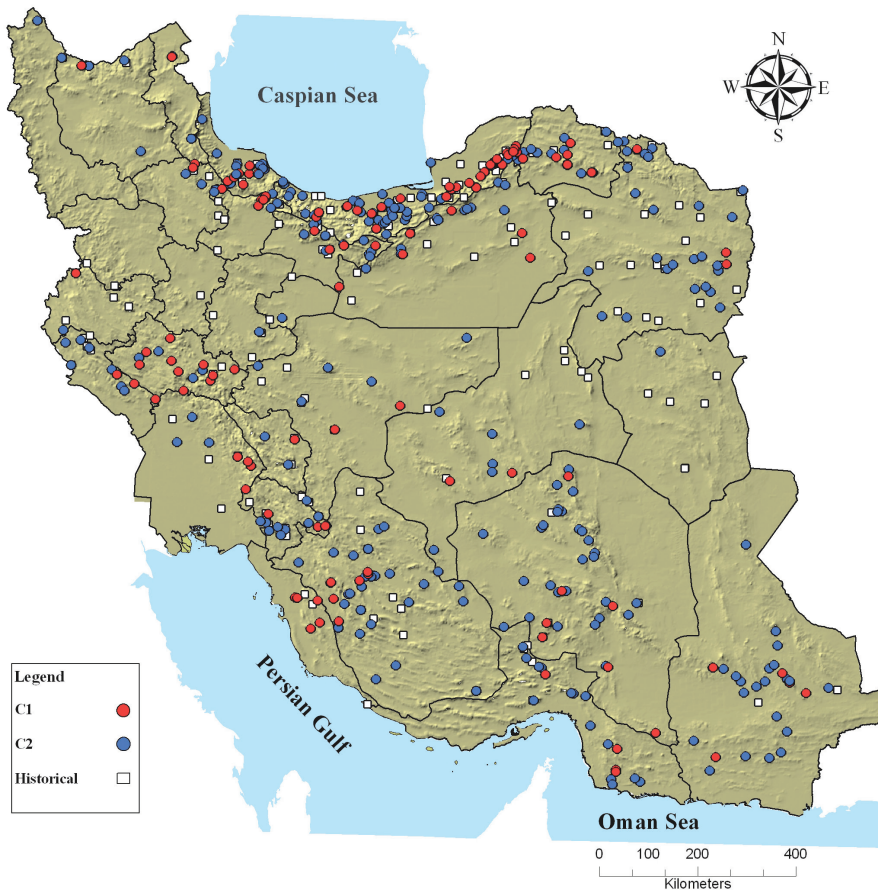
leopards are present are protected habitats. This is in agreement with findings of Kiabi et al. (2002).

Kiabi et al. (2002) guesstimated the leopard population size in Iran at 550-850 individuals spread over a range of 885,300 km<sup>2</sup>, which translates into a low density of 0.06-0.1 individuals/100 km<sup>2</sup>. Ghoddousi et al. (2008a, 2010) camera trapped 7 individuals and estimated the leopard density at 1.87 ± 0.07 individuals/100 km<sup>2</sup> in Bamu NP, Fars Province. In contrast, the study by Kiabi et al. (2002) guesstimated the leopard number in Bamu NP at 15-20 individuals. Whether this discrepancy results from actual population decline or it derives from different methodologies is unclear.

Presence of the leopard in Boushehr Province was occasionally reported by local settlements in the years before 1993. In 1993, a leopard was found dead in Dashtestan Township by rangers of Dashtestan DoE office. Later on the species was recorded in Dashtestan Township, Eram district in 2005 and 2009 and Borazjan city in 2007 (Jokar 2011, Boushehr Provincial DoE Office unpubl. records). In 2008, an adult male leopard was camera-trapped in Khaeez area, Bushehr Province, thus confirming the predator's presence in this area (Abdoli et al. 2008). Ongoing camera trapping surveys (1,600 trap nights) in

Gisekan non-protected area in Bushehr Province, identified 1 female and 2 male leopard individuals (Sanei 2016a). Leopard detections were also made in Abbas-Abad WR, Esfahan Province (Farhadinia et al. 2008).

Leopard numbers were estimated at 2-3 leopards in Marakan PA, 10-12 in Kiamaki WR and 7-9 in Arasbaran PA. However, the reliability of these estimates has still to be tested. Only sporadic leopard occurrence was detected in Lisar PA (Lukarevsky et al. 2007). To study the current distribution, a total of 190 questionnaires were filled by provincial DoE offices about presence records, human/livestock-leopard conflicts, threats and conservation needs from 2007 to 2011. Data from interviews with hunters, local shepherds and villagers were only accepted if relative hard facts and proofs were found. We refused to use non validated information from interviews with local shepherds and villagers for mapping the leopard presence localities mainly because these data is not reliable enough. Complaints from local people about livestock-leopard conflicts were accepted if confirmed by any of us, DoE experts or wildlife wardens. We accumulated a total of 554 leopard records (141 records classified as C1 and 413 records classified as C2) including both repeated (two or several records referring to the same location) and single



**Fig. 2.** Leopard presence point locations in Iran assessed from 2007 to 2011. C1 = confirmed presence, C2 = probable presence; sources for the historical records: Etemad (1985), Ziaie (1996), Kiabi et al. (2002), Sanei (2004, 2007) and unpubl. reports of DoE provincial offices. Administrative division of provinces refers to the initiation of data collection activities in 2007.

records. A total of 65 protected areas out of 204 (31.9%) were identified as leopard presence areas, of which 30 were classified as C1 and 35 as C2. In fourteen protected areas (6.8%) leopard is absent and in 125 (61.3%) protected areas the presence/absence status is unclear. PAs identified as leopard absence areas are non-suitable habitats with confirmed long-term and historically non-presence of the leopard. Unclear presence/absence status implies that even though the area has been surveyed, non-detection does not certainly mean absent due to the cryptic nature of the leopard and availability of suitable habitat types in the relative 125 PAs. Furthermore, 55 localities in non-protected habitats were categorised as C1 and 233 localities in non-protected habitats as C2 (Table 2; Fig. 2). Previous studies, related to the years before 2006, reported a total of 74 protected areas with leopard presence (Sanei & Zakaria 2011a) while there are 65 sites in the current study. It is unclear whether the other nine areas no longer contain leopards or surveys failed to detect the species. These

nine areas are: (1) Muteh WR, Esfahan Province, (2) Haftad Gholeh PA, Markazi Province, (3) Sorkheh Hesar NP, Tehran Province, (4) Lar NP, Tehran Province, (5) Bisotun WR and PA, Kermanshah Province, (6) Buzin and Markhil PA, Kermanshah Province, (7) Varmanjeh, Kermanshah Province, (8) Ruchun WR, Kerman Province, and (9) Oshtoran Kuh PA, Lorestan Province. These sites should be given priority for leopard surveys.

In Markazi province a single leopard track and faeces were detected in Haftad Gholeh PA (Talebi pers. comm.), where leopards were previously recorded (Sanei 2007). After completion of data collection for this assessment (2011), camera trappings in Haftad Gholeh PA successfully recorded leopard presence in the area (Markazi provincial DoE office unpubl. data).

#### Habitat

Throughout their range in Iran, Persian leopards are mostly confined to the mountainous areas (Sanei & Zakaria 2011a). Mobargha (2006) showed that elevations of 1,100-1,200

m and slopes of 30-65° contain the most suitable leopard habitats in Turan NP and PA, Semnan Province, while unsuitable plateaus occupy most of the study area. Omid et al. (2010) concluded that the best leopard habitats in Kolah Ghazi NP, Esfahan Province, are located at 1,800-2,400 m, on 20-70° slopes and in rocky mountainous areas. Gavashelishvili & Lukarevskiy (2008) concluded that leopards avoid snow cover, deserts and anthropogenic landscapes. Sanei & Zakaria (2008, 2011a) reported that leopards in Iran live in temperatures ranging from -23.1 °C to 49.4 °C. However, leopards were mostly recorded in areas with mean annual temperature of 13-18 °C, duration of ice cover <20 days/year and precipitation >200 mm/year.

#### Ecology and behaviour

Ghoddousi et al. (2008b) studied the frequency and distribution of territorial marking of leopards in Bamu NP by scrapes (mean length 39.3 ± 1.06 cm, mean width 22.7 ± 0.66 cm, mean depth 4.7 ± 0.18 cm, n = 48), often combined with urination and defecation, all over the park. Most of scrapes were produced in winter during mating season which is similar to a report from Sarigol NP, North Khorasan Province, where the mating season was demonstrated to last from January to February (Farhadinia et al. 2009; Fig. 3).

#### Disease

Diseases of the Persian leopard are poorly studied, thus, their implications for the conservation of this large cat species is unknown. Youssefi et al. (2010) reported about *Ancylostoma tubaeforme* in a young female leopard shot in the Ahovan County near Damghan city, Semnan Province. Investigates of Masoudi Zanjani (2004), cited in Sanei (2007), report no parasites in leopard scats from Tandureh NP, Razavi Khorasan Province. Sanei (2006, unpubl. report) carried out a parasitological survey throughout Golestan NP, Golestan Province and found *Shistosoma* spp. in the Degarmanli site. More recently in 2011, a leopard suffering from infectious disease was found near the Rashvanlu village, North Khorasan Province.

#### Prey species

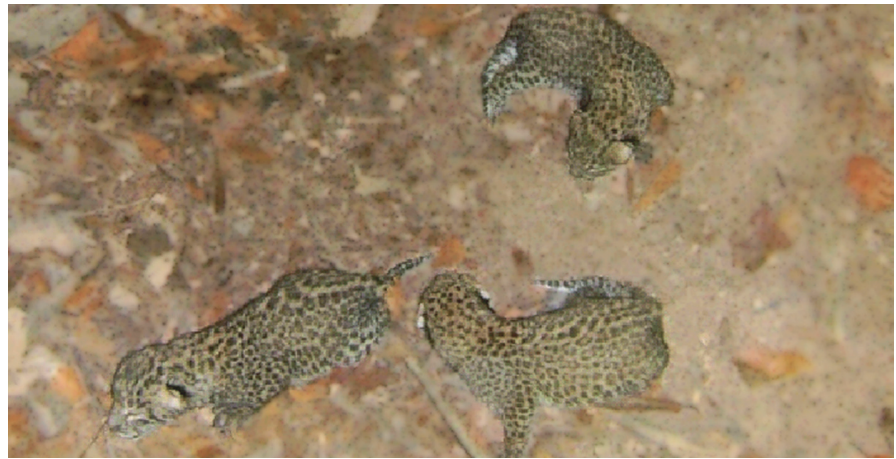
The staple prey species are the wild goat *Capra aegagrus*, wild sheep *Ovis orientalis*, wild boar and Indian crested porcupine *Hystrix indica* with 100%, 95%, 65%, and 65%, respectively, conformity of distribution with the leopard range in 43 study sites across

the country. Other species, such as the goitered gazelle *Gazella subgutturosa*, chinkara *G. bennetti*, roe deer *Capreolus capreolus*, red deer *Cervus elaphus*, and Persian onager *Equus hemionus onager* have limited distribution as well as less conformity with leopard range (Sanei 2007, Sanei et al. 2011; Fig. 4). Likewise, more detailed studies identified the main prey species as wild goat and wild sheep in Tandoureh NP, Razavi Khorasan Province and wild boar followed by wild sheep and wild goat in Golestan NP, Golestan Province (Chalani 2005, Sherbafi 2010). Meanwhile, wild goat was identified as a principle determinant for leopard presence in Kolah Ghazi NP, Esfahan Province (Omidi et al. 2010).

### Main threats

Sanei & Zakaria (2011b) describe seven threats to leopards in Iran, in decreasing order of incident frequency: (1) habitat destruction, degradation and fragmentation; (2) illegal hunting and poaching of both leopards and prey species, poisonous lures, capturing juveniles of prey species; (3) animal husbandry and presence of livestock in the leopard range; (4) lack of conservation facilities; (5) low environmental awareness; (6) droughts and unsuitable habitat conditions; (7) aftermath of Iran-Iraq war (i.e. unsafety in habitats, excess of gun among people, reduction in prey population, presence of land mines in the habitats). Kiabi et al. (2002) indicated that accidental and deliberate killing and habitat loss are the principal threats to the leopards in Iran. Ghoddousi et al. (2008a, 2010) describe habitat loss and fragmentation as the main threats to leopards in Bamu NP, Fars Province. We recorded a total of 71 cases of mortality throughout the country from 2007-2011 (see also Sanei et al. 2012). Intentional killing and poisoning ( $n = 50$ , 70% of total mortality) followed by road accidents ( $n = 13$ ) were the main causes of leopard mortality in recent years. Other detected causes of mortalities were disease ( $n = 3$ ), flood ( $n = 1$ ), intraspecific conflicts ( $n = 1$ ), natural death ( $n = 1$ ) and 2 cases of unknown reasons. It is worth mentioning that, these results could have a bias since natural mortalities are scarcely detected.

Habitat encroachment and development projects also bring about human-leopard conflicts, which increase every year. Sanei (2007) and Sanei & Zakaria (2011b) studied human-predator conflict cases in Iran in 2002-2003 and revealed that in 2002, ranking of conflicts with leopard was second after conflicts with



**Fig. 3.** Three new-born leopard cubs in a small cave located in a Forest in Neka Township, Mazandaran Province found by a local villager in May 2009 while their eyes were still closed (Photo: H. A. Khanehsari Naghash).

wolf *Canis lupus*. Yet in 2003, human/livestock-leopard conflict was in the third place, after conflicts related to wolf and brown bear *Ursus arctos*. We recorded known cases of such conflicts from 2004-2009. These cases include attacks of the leopard on cattle, camel, domestic sheep and goat, donkey, horse and herding dog. Rarely, attacks on humans, causing injuries, were also recorded (data available from the first author).

Recently, an innovative insurance model has been developed to address livestock-leopard conflicts and relative revenge killings by local people. Since the wolf distribution in Iran is comparable to that of the leopard in the country, attempts by local people for revenge killing (e.g. using poisonous lure in the habitat) may also affect the leopard. Therefore, even though livestock depredation by wolf is known to be much more frequent than by leopard, this insurance model has addressed both species at the same program to practically settle the issue (Sanei 2016b). Data on livestock – leopard/grey wolf conflicts from 2013 to early 2015 (26 months) shows that the most attacks include medium sized livestock (i.e. a total number of 7,090 goat and sheep) and less depredation on large sized cattle (i.e. cow, horse, camel, donkey and mule; 208 kills). Conflicts in the Provinces of Sistan and Balouchistan, Hormozgan, Razavi Khorasan, Kohgiluyeh and Boyer Ahmad, Kerman, Mazandaran, Fars and Ardebil were recorded to result in more than 500 losses/year in each province. Yet, we believe much cases of livestock losses particularly in Provinces of Gilan, Mazandaran and Golestan (within Hyrcanian forests range), remain unknown/not reported and thus, there could be significantly more cases than reported here.

Droughts and dry conditions in various habitats have become a serious threat for wildlife species in recent times. Numerous springs have also dried up because of unwise cultivation programmes and overuse of underground waters (Sanei & Zakaria 2011b). According to DoE, dry conditions in a number of habitats under the auspices of DoE entail distant migrations of ungulates, particularly from protected areas to outer human-dominated landscapes. Sistan and Baluchistan Province is one of the driest provinces in Iran where long-term livestock-leopard conflicts ignited by droughts and prey deficiency have not been solved for more than a decade.

### Discussion

*Fragmentation of the Iranian northern and southern leopard range*  
Comparing leopard presence sites reported earlier (Sanei 2004, 2007, Sanei & Zakaria 2011a) with those in this assessment (Fig. 2) suggests a considerable reduction in leopard distribution range over the past years. Considering this result, we hypothesise that leopard distribution in Iran is in the process of splitting into a northern and a southern range. The conjunction of two mountainous ranges of Alborz and Zagros in north-west of Iran has historically provided a link connecting the northern to the southern leopard range. Yet, we did not find any strong evidence of leopard presence in the 4 Provinces of Kordestan, Hamedan, Markazi (except for a camera trap record after data collection span) and Ghom. In Kermanshah Province only one dead leopard was found in 2008 in Paveh township located in the north-west of the Province. Furthermore, no recent record is available from the central and southern parts of West

Azərbaycan Province. In Hamedan Province, leopard absence for over three decades (Sanei 2004) might be a result of high village densities. Local authorities explained that historically the species inhabited Ghafelanteh Mountain located in Shara PA in this province (Nouri, pers. comm.). Even though, questionnaire surveys also failed to detect any C1 or C2 record of leopard presence, unconfirmed evidences of leopard presence were reported by local villagers in Marivan township in Kordestan Province. This may indicate that the species still inhabits the area (Imani and Veisi, pers. comm.).

The main Persian leopard population is known to be in Iran (Kiabi et al. 2002, Stein et al. 2016) and could potentially support leopard presence in the neighbouring countries (Sanei et al. 2013, Farhadinia et al. 2015b). But rapid development is affecting its survival in various regions of its range. Sanei & Masoud (2014) reported that much of the leopard habitat in East-Azərbaycan Province (bordering Armenia and Azerbaijan) is fragmented by cultivation lands and settlements while only few prime habitat in the north (i.e. above 37° 00' N) is still reasonably vast and connected.

#### *A preliminary analysis*

Estimation of the correlation between prey variables, size and IUCN category of protected areas, and the years under protection in 104 protected areas out of 204 sites where leopard presence study was conducted has revealed interesting patterns:

1. The IUCN category of protected areas strongly correlates with prey numbers and densities ( $r = -0.38$  to  $-0.31$ ,  $P = 0.000$  to  $0.001$ ): The higher the protection status, the higher are ungulate numbers and this relationship is equally strong for all studied prey species, except for gazelles. Hence, in general NPs contain more prey than WRs and those more than PAs. This

could be a result of more resources available and higher awareness together with stricter law enforcement in the higher-ranked sites.

2. The size of protected area is strongly linked to wild goat numbers ( $r = 0.29$ ,  $P = 0.003$ ), i.e. the larger the area, the more wild goats.
3. The number of years under protection is important for wild goat and wild sheep numbers ( $r = 0.29$ ,  $P = 0.003$  and  $r = 0.28$ ,  $P = 0.005$ , respectively) which implies that performance of the protected area network in Iran has been significant so far.

Study of protected areas with leopard presence (1)/absence (0) together with data on prey species shows that leopard occurrence in Iran's protected areas is strongly linked with wild goat densities and, to a lesser extent, with wild sheep densities. This is in agreement with findings of previous studies about co-occurrence of the leopard with wild goat followed by the wild sheep (Sanei et al. 2011). Wild boar is also one of the staple prey species for the Persian leopard. Boars faced intensive poaching and hunting in some regions more recently. Thus, information and monitoring of its abundance, distribution and principle threats is essentially required.

#### *Protection measures and recommendations*

DoE implements certain compensation programmes for agricultural products lost to wildlife, but it is practically impossible to recoup all the actual losses inflicted by leopards, ungulates and porcupines and to monitor this work in villages scattered throughout the country. Furthermore, local people in numerous rural villages are not aware of compensation regulations and laws. Currently, a particular and innovative insurance programme for livestock to compensate and reduce losses caused by leopards and wolves is ongoing as a part of the Persian leopard

national conservation and management action plan (Sanei 2016b). Informing local villagers about these programmes followed by compensating the losses in a reasonable period of time may effectively reduce revenge killings (Fig. 5).

Golestan Province contains vast areas of suitable habitat connecting leopard range in the north-east with the northern parts of the country. Among all 24 mortalities recorded in Golestan Province from 2002 to 2011, 5 cases were road kills, 1 individual drowned in a flood, 1 died from unknown causes and 17 (70.8%) were shot or poisoned. Moreover, 12 individuals were intentionally killed in this province since 2007 (Shakiba, pers. comm., Golestan DoE General Office, unpubl. records). Since the leopard has been considered a protected species in Iran, there could be a higher number of individuals shot or intentionally killed throughout the country that we failed to detect, as people may not report cases due to fear of legal prosecution. We believe that conducting community based programmes to empower local communities to effectively protect their herds and livestock could be a practical solution to reduce revenge killing by local herders and villagers. Road accidents comprise about 18% of the assessed leopard mortalities in Iran from 2007 to 2011 (see also Sanei et al. 2012). This has been a particular threat to the leopard in various provinces; e.g. a highway crossing Golestan NP in Golestan Province is a threat to the leopard and other wildlife, such as red deer, in this area. A proposal of relocating and replacing the highway is under consideration. Yet, assessment of leopard road kill hotspots and spatial patterns to identify the mitigation measures and priorities together with evaluating the use of wildlife bridges or underpasses in certain areas where the highest numbers of animal collisions with vehicles occur is required.



**Fig. 4.** Landscapes of the leopard habitat and its main prey species in North Khorasan Province (left: wild sheep, right: wild goat; Photos Behrouz Jafari).

As the Iranian leopard serves as a source population for neighbouring regions, identification of transboundary leopard habitats and corridors among Iran and bordering areas as well as transboundary cooperation among neighbouring countries to improve the Persian leopard conservation in the region is a vital step towards the maintenance of free movements of leopards. In this regards, distribution modelling of the Persian leopard potential habitats in north-east and north-west of Iran as well as elsewhere across the country has been completed (Sanei et al. 2013, Sanei 2016b). Agreements to establish joint transboundary protected areas (i.e. peace parks) between Iran and Iraq as well as Iran and Armenia, have been signed. Besides, an urgent priority should be given to investigating the risk of fragmentation and the consequences of splitting the leopard distribution range in Iran into a northern and a southern range. Field surveys to assess corridors connecting leopard main habitats particularly in the provinces in north-west Iran are needed. Further conservation programmes, improving legislations and protective measures need to be planned accordingly.

To address all the aforementioned threats affecting the Persian leopard in Iran, DoE together with Asian Leopard Specialist Society has embarked on the preparation of a national conservation and management action plan since 2012. Subsequently, the plan was finalised and endorsed on January 2016 while it is covering a total of eleven main subjects at the local, national and international scales. These subjects are (1) awareness raising, training and empowerment, (2) habitat, (3) media, (4) veterinary and disease, (5) rehabilitation centers, (5) transboundary habitats and international cooperation, (6) genetic conservation, (7) compensation and innovative Persian leopard insurance program, (8) Persian Leopard National Network, (9) research, evaluation and monitoring, (10) protection unit and wildlife wardens and (11) laws and regulations (Sanei 2016b).

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**Fig. 5.** Leopard killed by villagers in Darab, Fars Province, South of Iran (Photo Fars Provincial DoE Office).

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