The Status of the Persian Leopard in Bamu National Park, Iran

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The Persian leopard *Panthera pardus saxicolor* is the largest member of eight felid species surviving today in Iran, after the extinction of the Asiatic lion *Panthera leo persica* and the Caspian tiger *Panthera tigris virgata* in the past 70 years. The stronghold of this endangered subspecies is Iran. Over the past 25 years the Persian leopard was exterminated in many areas of its global range and in the others its numbers have plummeted. Bamu National Park (BNP) has long been one of the best habitats for the subspecies in southern Iran, but leopards there face severe threats nowadays.

The leopard occurs widely in almost all types of habitats in Iran: snow-capped heights of the Alborz and Zagros mountains, rolling hills in central Iran, dense and humid forests along the Caspian Sea coast and arid cliffs and mountains fringing the Persian Gulf and Oman Sea (Firouz 2005). The leopard range covers about 850,000 km^2 of prey-sufficient habitats and avoids only the vast deserts of central Iran (Kiabi *et al.* 2002).

The first efforts at leopard research and conservation in BNP began in the 1970's by Bijan F. Dareshouri, the nation's premier wildlife scientist and conservationist, who used surveys of signs of presence and direct observations (B. F. Dareshouri, pers. comm. 2008). He guesstimated that 15-20 leopards live in BNP (Kiabi *et al.* 2002).

In June 2007, the *Persian leopard project* was initiated to assess the status and structure of the leopard population, to study the ecology, and to launch targeted conservation actions in BNP.

This paper presents and discusses our results from camera-trapping to assess the status of the leopard in BNP.

Methods

BNP (also referred to as Bamoo or Bamou) occupies an area of 485.94 km^2 in Fars Province to the north-east of Shiraz city between 29º36'24" and 29º53'12" N and 52º29'37" and 52º54'12" E (Fig. 1; Darvishsefat 2006). Established in 1967 and upgraded to a national park in 1970, it encompasses three parallel mountain ridges extending in an west-east direction and the hilly plains between them (Fig. 2). Topographically, BNP is confined to the northern macro-slope of the Zagros Mts. Elevations range from 1600 to 2700 m. The climate is semi-arid temperate, with hot and dry summers and cold, humid winters (Darvishsefat 2006). The western part of BNP is separated by the Isfahan-Shiraz highway and is deprived of large mammalian fauna due to poaching. Only the eastern part of BNP (360 km^2) has been effectively protected and is rich in biodiversity.

Camera-trapping was carried out in eastern BNP from late September 2007 until late May 2008, using the 35 mm film passive camera photo-traps Stealthcam MC2-GV. We used 30 photo-traps at first, but then 2 of them failed and 8 more were stolen. For convenience, this area was divided into 5 topographically distinct areas which were camera-trapped one after another. The photo-traps were set up along the established leopard trails (recognized from presence signs) on ridge tops and in valleys to ensure uniform coverage. The devices were mounted at ca. 40 cm above the ground on posts made of flat

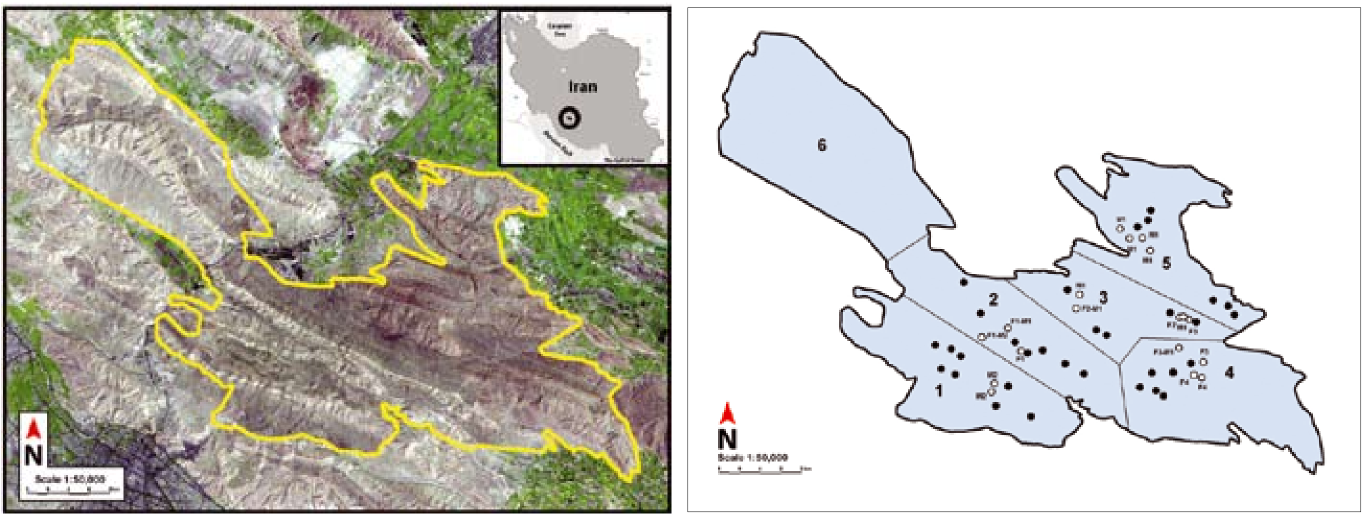

Fig. 1. Location of Bamu National Park in southern Iran (top) and location of the camera-trap stations within the defined areas in Bamu National Park (bottom). White spots are the stations with captures of the leopards with individual IDs and black spots are the stations without captures. Leopard IDs: M1 – Adult male, M2 – Sub-adult male, F1 – Female with cub, F2 and F3 – Adult females and F4 – Sub-adult female. The numbers 1 to 6 indicate the distinct areas of which the areas 1 to 5 were camera-trapped during this study.

Fig. 2. A typical landscape of Bamu National Park (Photo T. Ghadirian).

stones and on trees. Each camera-trap station consisted of two photo-traps placed not far from each other on the opposite sides of a trail so as to photograph leopards from both flanks. The photo-traps were set for 24-hour operation, dual photography regime and 1-minute intervals between successive photographs. The sites of all photo-traps were located by GPS Garmin 60 CS and plotted on the map in ArcGIS 9.0 for measurements, e.g. to define the boundary strip (see below).

The design of our study was identical to that described by Karanth *et al.* (2004). As we had 20 photo-traps and had to cover 5 areas with similar sampling effort, we set up the photo-traps in 20 sites (10 camera-trap stations, 2 units/station) within each area, for 21 successive days which corresponded to battery life. Thus, there were 21 sampling occasions, each of which combined captures from 5 days of photo-trapping (1 day from each area).

Photo-captured animals were sexed from external genitalia (males), presence of cubs (females) and general appearance (much larger body size, plump muzzle, wider chest and broader front limbs in males). Individuals were recognized from their unique spot and rosette patterns on flanks and limbs (Henschel & Ray 2003, Kostyria *et al.* 2003, Spalton *et al.* 2006).

We constructed the X-matrix of capture histories for individual leopards, excluding the dependent cub (0's for no captures, 1's for captures) and used CAPTURE software to estimate the leopard abundance and check the hypothesis of population closure (Karanth 1995, Karanth & Nichols 1998). Population density was estimated by dividing the estimate of population size by the effective area which includes the area confined within the outer camera-trap stations and the boundary strip (Henschel & Ray 2003, Soisalo & Cavalcanti 2006).

We also estimated leopard occupancy, i.e. part of the study area actually inhabited and used by the species, as described by Linkie *et al.* (2007). For this, we used the single-season subprogramme of freely downloadable PRESENCE 2.0 software. In the input form, we inserted 1's (leopard captures) and 0's (no captures) across the 21 sampling occasions (see above) and the 50 camera-trap stations (10 stations/area x 5 areas, see above). We used 6 pre-defined models which consider detection probability either constant or survey-specific and the sampled population as consisting of 1-3 arbitrary groups (MacKenzie *et al.* 2006).

Table 1. Results of occupancy modeling of the leopard population in Bamu National Park. Abbreviations: *p* – detection probability, AIC – Akaike's Information Criterion, ML – model likelihood, Ψ – occupancy, SE – standard error.

Model	AIC weight sum = 1	ML	ψ ± SE	*p* ± SE
1 group, constant *p*	0.80	1.00	0.56 ± 0.13	0.05 ± 0.01
2 arbitrary groups, constant *p*	0.11	0.14	0.56 ± 0.13	0.05 ± 0.01
1 group, survey-specific *p*	0.08	0.10	0.54 ± 0.12	0.05 ± 0.04
3 arbitrary groups, constant *p*	0.01	0.02	0.56 ± 2.44	0.05 ± 1.86

Results

The sampling effort of 1012 trap-nights yielded 31 independent leopard captures, resulting in a relative abundance index of 3.06 captures/100 trap-nights. The total number of leopard pictures was 72, but only 27 captures were used in the X-matrix due to re-captures within an occasion. We photographed 7 individual leopards across 21 sampling occasions: 1 adult male, 1 sub-adult male, 1 female with cub, 2 adult females and 1 sub-adult female (Fig. 3).

The sampling efforts in each of the five areas differed significantly about the mean ($\chi^2 = 14.51$, df = 4, P = 0.006), but this variation did not affect the numbers of individuals captured ($r^2 = 0.39$, $F_{1,3} = 1.95$, P = 0.257) nor the numbers of independent leopard photographs taken in each area ($r^2 = 0.25$, $F_{1,3} = 1.02$, P = 0.387). This difference in sampling effort was caused by difficult accessibility of some parts of BNP, trail obstructions in winter, theft and the malfunctioning of some camera-traps.

The model M(o) implying constant capture probabilities for individual leopards had the best fit (model selection criterion = 1.0) and the model M(h) of heterogeneity in capture probabilities was ranked the second (0.97). Nonetheless, we have chosen M(h) as its population estimator is robust and most relevant to solitary felids in comparison with M(o) (Karanth & Nichols 1998, Karanth *et al.* 2004, Maffei *et al.* 2004). Indeed, the wide-ranging adult male had a much higher chance of being photographed (12 out of 21 sampling occasions, 57.1%) compared with his conspecifics (females on 2-4 occasions (9.5-19.0%) and the sub-

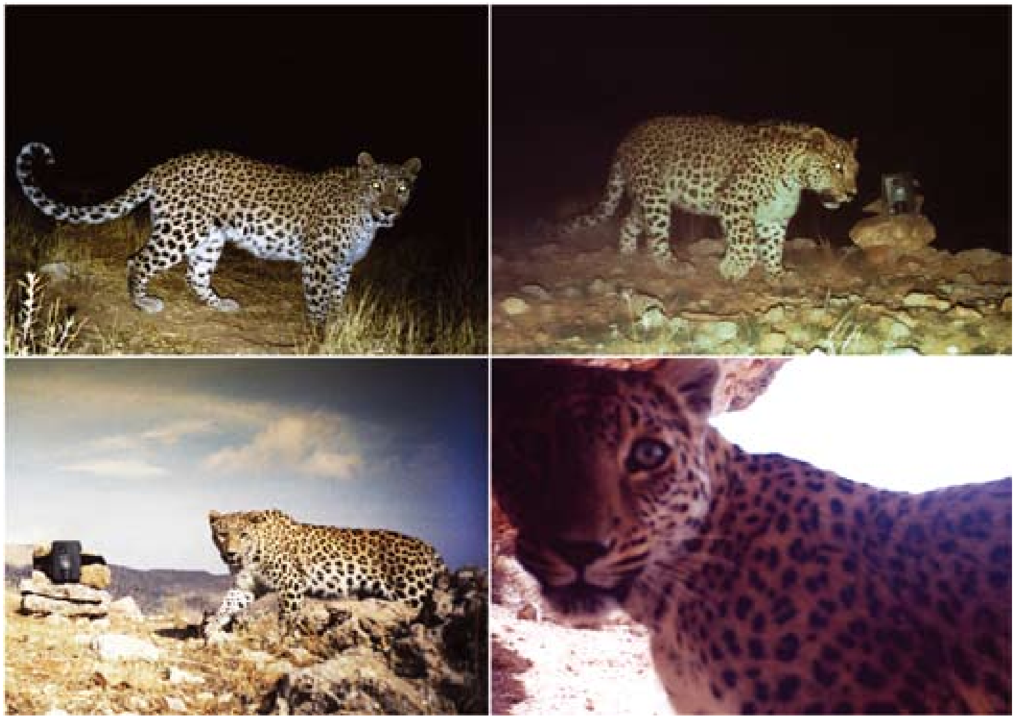

Fig. 3. The leopard photo-captures in Bamu National Park: adult female with cub (top left), adult male (top right), adult female (bottom left) and sub-adult female (bottom right; photos Plan for the Land Society).

adult male on 3 occasions or 14.3%). The goodness-of-fit of M(h) was statistically significant (χ^2 = 27.13, df = 20, P = 0.13). Jackknife was the best estimator of population abundance. The assumption of population closure was not violated (z = -0.22, P = 0.41).

The number of leopards in BNP estimated by jackknife M(h) was 6.00 ± SE 0.24 individuals, with the 95% confidence interval 6-6 individuals. It is most likely that such a narrow log-normal confidence interval was an artifact of the small sample size (Karanth 1995, Haines *et al.* 2006). The average capture probability of individual leopards in a sampling occasion (p-hat) was 0.21.

The mean maximum distance moved (MMDM), calculated as the arithmetic mean of the maximum distances moved (MDM) by 6 individuals between recaptures (0.62-12.38 km), was 5.01 ± 1.72 km. The boundary strip was half of MMDM or 2.50 ± 0.86 km. The effective area was 321.12 km^2, so the leopard density was 1.87 ± 0.07 individuals/100 km^2.

The best fit occupancy model having the highest Akaike's Information Criterion (AIC) weight shows that the detection probability of leopards in camera-trap stations is constant, that the population is represented by a single group, and that leopard occupancy in BNP is similar across the models (Table 1). Weighted mean occupancy, i.e. the sum of the products of AIC weight and occupancy in each model, is 0.56 so the leopard occupancy in BNP varies around 56% of the study area. This occupancy is 47% higher than the naïve estimate of occupancy (0.38 or 38%, 19 out of 50 camera-trap stations) due to several non-detections when present, which are ignored in the naïve estimate.

Discussion

The Persian leopard is the largest subspecies of this cat which is classified in the 2008 IUCN Red List of Threatened Species as "Endangered". The leopard is fully protected by laws issued by Iran's Department of Environment (DoE). Kiabi *et al.* (2002) have guesstimated the leopard population in Iran to number 550-850 individuals, which results in a crude density of 0.06-0.1 individuals/100 km^2. However, the leopard density is much higher inside protected areas (including BNP) which are quite large and thus capable of securing the survival of this cat (Kiabi *et al.* 2002). Using the guesstimates of leopard numbers in some protected areas of Iran (Kiabi *et al.* 2002) and the sizes of these areas (Darvishsefat 2006), the following rough estimates of leopard densities can be obtained: 3.4-5.1 leopards/100 km^2 in Golestan and Tandoreh national parks, 3.1-4.1 in Bamu National Park, 2.0-3.3 in Jahan Nama Protected Area and 0.5-1.1 in Dena Protected Area.

The most urgent threat is the ever-increasing fragmentation into a patchy network of distant and often too small sub-populations. Prey reduction from poaching, infrastructure development, disturbance and habitat loss (collection of edible plants, mining, road construction, deforestation, fire and livestock grazing) are the driving forces of range fragmentation, leaving vast tracts of mountainous habitats unsuitable for resident leopard subpopulations (Khorozyan *et al.* 2005, Lukarevsky *et al.* 2007). Only a handful of protected areas (all in Iran) are large enough to maintain viable Persian leopard subpopulations (Kiabi *et al.* 2002, Breitenmoser *et al.* 2007). In Iran, direct poaching occurs as shooting to alleviate predation on livestock (Kiabi *et* *al.* 2002, Farhadinia *et al.* 2007, Abdoli *et al.* 2008). It is not widespread, but makes a substantial impact on population viability due to the small population size.

The leopard density in BNP is much higher than generally in Iran (see above) and than in two other areas where it was estimated from camera photo-trapping: in Jabal Samhan Nature Reserve in Oman (0.4 ind./100 km^2; Spalton *et al.* 2006), and in the Russian Far East (1.1-1.2 ind./100 km^2; Kostyria *et al.* 2003). Quite a high density of territorial markers such as scrapes is further evidence (Ghoddousi *et al.* 2008). However, the leopard density is lower than in equatorial rain forest in Gabon (2.7-12.1 ind./100 km^2) where the same photographic capture-recapture technique was used (P. Henschel *pers. comm.* 2008).

Our estimate of leopard density in BNP is much lower than previously estimated (Kiabi *et al.* 2002). Whether this discrepancy indicates a population decline is unknown, as completely different methodologies were used in the two cases.

Leopard occupancy in BNP is significantly higher when non-detections at presence (false absence) are taken into account. This often happens with secretive and rare species (MacKenzie *et al.* 2006). The leopard, despite being a naturally cryptic species, is at least vulnerable in BNP in the face of current threats.

The principal threat to leopard in BNP is ever-increasing fragmentation caused by the Isfahan-Shiraz highway and agricultural lands; these split habitats apart and eases access for poachers and shepherds.

In summer 2008 we started the Rufford Small Grant project to improve leopard conservation in BNP through intensive campaigning and the establishment of the game wardens' Persian Leopard Trust. We also plan to expand leopard research and monitoring in BNP and other areas of Iran to study leopard diet, distribution, population structure, relationships with prey and interactions with other carnivores, and to initiate monitoring of leopards and their prey. Implementation of these activities over the years will allow us to reveal the population trends, and monitor the course of conservation efforts and the leopard's response to them.

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References

Abdoli A., Ghadirian T., Khaleghi Hamidi A., Mostafavi H., Moshiri H., Pour'salem S. and Ghoddousi A. 2008. First evidence of Persian leopard from Khaeez area, southern Iran. Cat News 48, 17.

Breitenmoser U., Breitenmoser-Würsten C., Mörschel F., Zazanashvili N. and Sylven M. 2007. General conditions for the conservation of the leopard in the Caucasus. Cat News Special Issue 2, 34-39.

Darvishsefat A.A. 2006. Atlas of protected areas of Iran. University of Tehran Press, 157pp.

Farhadinia M., Nezami B., Mahadavi A. and Hatami K. 2007. Photos of Persian leopard in Alborz Mountains, Iran. Cat News 46, 34-35.

Firouz E. 2005. The complete fauna of Iran. London I.B. Tauris & Co Ltd., 322 pp.

Ghoddousi A., Khaleghi Hamidi A., Ghadirian T., Ashayeri D., Hamzehpour M., Moshiri H., Zohrabi H. and Julayi L. 2008. Territorial marking by Persian leopard (*Panthera pardus saxicolor* Pocock, 1927) in Bamu National Park, Iran. Zoology in the Middle East 44, 101-103.

Haines A.M., Janecka J.E., Tewes M.E., Grassman Jr. J.E. and Morton P. 2006. The importance of private lands for ocelot *Leopardus pardalis* conservation in the United States. Oryx 40, 90-94.

Henschel P. and Ray J. 2003. Leopards in African rainforests. Survey and monitoring techniques. WCS Global Carnivore Program, 50 pp.

Karanth K.U. 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. Biological Conservation 71, 333-338.

Karanth K.U., Chundawat R.S., Nichols J.D. and Kumar N.S. 2004. Estimation of tiger densities in the tropical dry forests of Panna, central India, using photographic capture-recapture sampling. Animal Conservation 7, 285-290.

Karanth K.U. and Nichols J.D. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79, 2852-2862.

Khorozyan I., Malkhasyan A. and Asmaryan S. 2005. The Persian leopard prowls its way to survival. Endangered Species Update 22, 51-60.

Kiabi B.H., Dareshouri B.F., Ghaemi R.A. and Jahanshahi M. 2002. Population status of the Persian leopard (*Panthera pardus saxicolor* Pocock,1927) in Iran. Zoology in the Middle East 26, 41-47.

Kostyria A.V., Skorodelov A.S., Miquelle D.G., Aramilev V.V. and McCullough D. 2003. Results of camera trap survey of Far Eastern leopard population in southwest Primorski Krai, winter 2002-2003. Vladivostok, 22 pp.

Linkie M., Dinata Y., Nugroho A. and Haidir I.A. 2007. Estimating occupancy of a data deficient mammalian species living in tropical rainforests, sun bears in the Kerinci Seblat region, Sumatra. Biological Conservation 137, 20-27.

Lukarevsky V., Akkiev M., Askerov E., Agili A., Can E., Gurielidze G., Kudaktin A.N., Malkhasyan A. and Yarovenko Y.A. 2007. Status of the leopard in the Caucasus. Cat News Special Issue 2, 15-21.

MacKenzie D.I., Nichols J.D., Royle J.A., Pollock K.H., Bailey L.L. and Hines J.E. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, 324 pp.

Maffei L., Cuellar E. and Noss A. 2004. One thousand jaguars (*Panthera onca*) in Bolivia's Chaco? Camera trapping in the Kaa-Iya National Park. Journal of Zoology, London 262, 295-304.

Soisalo M.K. and Cavalcanti S.M.C. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture-recapture sampling in combination with GPS radio-telemetry. Biological Conservation 129, 487-496.

Spalton A., Al Hikmani H.M., Willis D. and Said A.S.B. 2006. Critically endangered Arabian leopards *Panthera pardus nimr* persist in the Jabal Samhan Nature Reserve, Oman. Oryx 40, 287-294.

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