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Abstract: 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 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 km² 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 km² in Fars Province to the north-east of Shiraz city between 29°36’24” and 29°53’12” N and 52°29’37” and 52°54’12” E (Fig. 1; 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 km²) 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.
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).

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 (χ² = 14.51, df = 4, P = 0.006), but this variation did not affect the numbers of individuals captured (r² = 0.39, F₁,3 = 1.95, P = 0.257) nor the numbers of independent leopard photographs taken in each area (r² = 0.25, F₁,3 = 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-

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.

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC weight sum = 1</th>
<th>ML</th>
<th>ψ ± SE</th>
<th>p ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 group, constant p</td>
<td>0.80</td>
<td>1.00</td>
<td>0.56 ± 0.13</td>
<td>0.05 ± 0.01</td>
</tr>
<tr>
<td>2 arbitrary groups, constant p</td>
<td>0.11</td>
<td>0.14</td>
<td>0.56 ± 0.13</td>
<td>0.05 ± 0.01</td>
</tr>
<tr>
<td>1 group, survey-specific p</td>
<td>0.08</td>
<td>0.10</td>
<td>0.54 ± 0.12</td>
<td>0.05 ± 0.04</td>
</tr>
<tr>
<td>3 arbitrary groups, constant p</td>
<td>0.01</td>
<td>0.02</td>
<td>0.56 ± 2.44</td>
<td>0.05 ± 1.86</td>
</tr>
</tbody>
</table>

Fig. 2. A typical landscape of Bamu National Park (Photo T. Ghadirian).
The goodness-of-fit of M(h) was statistically significant ($\chi^2 = 27.13$, 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 km², so the leopard density was 1.87 ± 0.07 individuals/100 km².

The best fit occupancy model having the highest Akaiki’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 km². 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 km² 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).
Panthera 2

Panthera pardus saxicolor 2

to initiate monitoring of leopards and interactions with other carnivores, and structure, relationships with prey and leopard diet, distribution, population BNP and other areas of Iran to study leopard research and monitoring in Leopard Trust. We also plan to expand establishment of the game wardens’ Persian intensive campaigning and the estab

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nivin viability due to the small popula

the course of conservation efforts and the leopard’s response to them.

Acknowledgements

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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 Ruf

ford 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 moni

References


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