Critically Endangered Arabian leopards *Panthera pardus nimr* persist in the Jabal Samhan Nature Reserve, Oman

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Abstract Between 1997 and 2000 a survey of the Arabian subspecies of leopard *Panthera pardus nimr* was conducted in the little known Jabal Samhan Nature Reserve in southern Oman. Using camera-traps 251 photographic records were obtained of 17 individual leopards; nine females, five males, two adults of unknown sex and one cub. Leopards were usually solitary and trail use and movements suggested large ranges characterized by spatial sharing but little temporal overlap. More active by day than night in undisturbed areas, overall the leopards exhibited two peaks in activity, morning and evening. The survey also provided records of leopard prey species and first records of nine Red List mammal species previously unrecorded in Jabal Samhan. Although people are mostly absent from the Reserve there is some conflict between leopards and shepherds who live outside the Reserve. The numbers and activities of frankincense harvesters in the Reserve need to be managed to safeguard the leopard and its habitat. The main challenge for the future is to find ways whereby local communities can benefit from the presence of the Reserve and from the leopards that the Reserve seeks to safeguard.

Keywords Arabia, Arabian leopard, camera-traps, Dhofar, Jabal Samhan, leopards, Oman, *Panthera pardus nimr*.

Introduction

The Arabian subspecies of leopard *Panthera pardus nimr* is categorized as Critically Endangered on the IUCN Red List (IUCN, 2006), is listed on CITES Appendix I (Nowell & Jackson, 1996), and is restricted to small populations on the Arabian Peninsula with a total population estimated at <250 (EPAA, 2003). In Oman, where hunting or capture is illegal, the leopard no longer occurs in Al Hajar mountains in the north and reports of a few individuals in the Musandam Peninsula are unsubstantiated. However, camera traps have recorded leopards in the southern mountains of Dhofar (Spalton & Willis, 1999). These mountains comprise Jabal Qamar, Jabal Qara and Jabal Samhan and form a crescent shaped range from the Yemen border east to the Arabian Sea. Thomas (1932) and Thesiger (1949) noted leopards in Jabal Qara, and a leopard in the Natural History Museum (London, UK) is thought to have come from Jabal Samhan in 1947, and a further specimen was obtained elsewhere in Dhofar in 1947–1948 (Harrison, 1968).

It was not until 1977 that the first biological survey was carried out in the Dhofar mountains, although little attention was devoted to the high and least accessible Jabal Samhan. The only records of leopards from the survey were two skins from the area of Jabal Samhan (Reade *et al.*, 1980). Eight years later an expedition caught four leopards in Jabal Samhan to establish the first captive breeding group for this species (Usher Smith, 1985) and in 1995 the first photographs of the species in the wild were obtained using a camera-trap (Spalton & Willis, 1999). In 1997 Jabal Samhan was declared a Nature Reserve and in the same year the Arabian Leopard Survey was instigated to study the leopards of the area.

Here we present the results of a camera-trapping programme for 1997–2000, describe the distribution, movements and activity patterns of leopards in Jabal Samhan and human activities in the area, and discuss the implications of our findings for the conservation of this small population. We also report on the occurrence of other large mammals, some of which are important leopard prey species.

Study Area

Jabal Samhan, containing the 4,500 km^2 Jabal Samhan Nature Reserve, is the most north-easterly of the Dhofar

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Received 4 March 2005. Revision requested 10 June 2005. Accepted 19 September 2005.

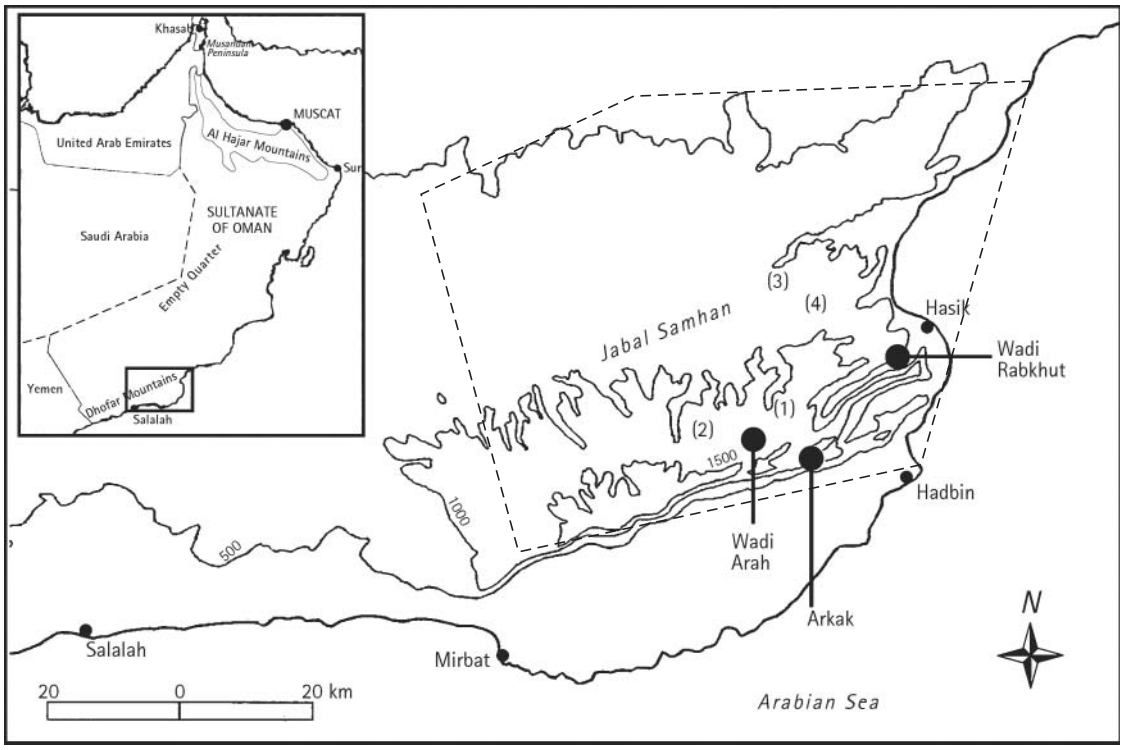

Fig. 1 Jabal Samhan Nature Reserve in southern Oman (approximate boundaries indicated by dashed line) showing the camera-trap study areas in Wadi Rabkhut, Wadi Arah and Arkak, and the locations of temporary camera-traps (1–4, see text for details).

mountains, rising steeply from the coastal plain to an escarpment at >2,100 m (Fig. 1). The mountain top is a rolling plateau dissected by 500–1,000 m deep gorges or wadis that flow, when in flood, north to the gravel plains or east to the sea. Jabal Samhan is less affected by the clouds of the summer south-west monsoon, which form along the escarpment in June - August but usually leave the summit dry, than is Jabal Qara to the west. Away from the escarpment summer conditions are hyper-arid and hot, with shade temperatures >45°C in June.

Although the flora and fauna of Jabal Qara has been studied (Reade *et al.*, 1980; Miller & Morris, 1988) little is known about that of Jabal Samhan. The sparse vegetation of the plateau is dominated by *Acacia* spp., *Commiphora* spp. and frankincense *Boswellia sacra*; other tree species, such as *Dracaena serrulata,* are less widespread. The deep gorges support a greater density of vegetation, dominated by frankincense, *Ficus* spp., *Acacia* spp. and the palm *Nannorrhops ritchieana*. The south-facing escarpment is more heavily wooded, with dominant *Acacia* spp. and a dense shrub community.

There is no written history of human settlement in Jabal Samhan. Local information indicates that up until the mid 1970s people lived in the mountain as nomadic shepherds and for the harvesting of frankincense for trade. Today few local people enter the area but frankincense harvesters, with donkeys, periodically establish temporary camps.

Methods

The Arabian leopard has rarely been seen alive in the wild and thus could not be studied by direct observation. However, camera traps have been successfully used for leopards in Oman since 1995 (Spalton & Willis, 1999).

The *Trailmaster* system (*Trailmaster Inc*., USA) has been described by Kucera & Barrett (1993). TM1500 camera-traps were programmed to operate for 24 hours and time between successive photographs was set to 5 minutes. The units recorded time and date. In September 1997 and August 1998 we surveyed the area on foot to locate suitable areas for the camera-traps (Spalton & Willis, 1999). Three areas, where most evidence of leopards was found, were selected (Fig 1). Two camera-traps were installed in Wadi Rabkhut, a deep gorge near the eastern end of the mountain and 10 km from the sea. Four camera-traps were positioned at and around the confluence of Wadi Arah and a smaller side gorge in the centre of the high mountain. Two camera-traps were positioned at Arkak, an area of the southern escarpment, one on a trail that led down the escarpment and one east along the escarpment top. Four temporary camera-traps were lifted by

helicopter into inaccessible locations in the centre of the mountain for October – December 1998. All cameras were removed in November 2000.

Results

Camera-traps operated on average for 80% of the study period between September 1997 and November 2000; the highest rate of coverage for a single trap being 89% or 1,024 days. The analysis is restricted to 1,036 photographs of an animal or person. There were 251 records of leopards, 24% of all photographs. Other wildlife, local people (or their livestock) and frankincense harvesters (or their donkeys) accounted for 45, 16 and 15% respectively.

Leopard

At the eight permanent camera-traps leopards were recorded on average every 29 days (range 19 – 43 days). Apart from cheek rubbing the units or looking closely at the camera leopards showed little reaction (Plate 1). In only 13 photographs did leopards (all female) seem to be alarmed by the camera-traps. Individual identities of the 17 leopards were determined by the shape of rosettes on their coats, with nine females, five males, two adults of unknown sex and one cub identified. Some individuals were recorded throughout the study, others for only part, and some were rarely seen (Table 1). There was no overlap in trail use between leopards in Wadi Rabkhut and those in Wadi Arah or Arkak but some individuals moved between Wadi Arah and Arkak.

Two males (M1 & M2) and two females (F1 & F2) used Wadi Rabkhut. M1, who appeared old and emaciated, was present from the beginning of the study, passing through on average every 21 days but was not seen after November 1998. His disappearance was followed by the arrival of M2 in February 1999. F1 was present from the beginning of the study to January 1999, and F2 from November 1998. F2 was recorded with a young (<6 months old) cub on 31 January 2000. There was one record of a single female (F8) in the Wadi in May 1999 and an animal of unknown sex in August 1998.

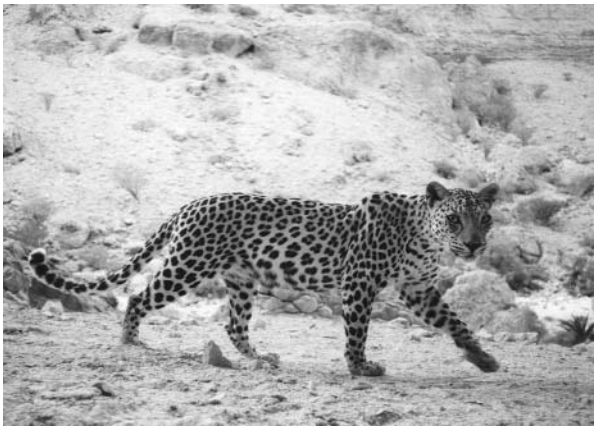

Plate 1 Self portrait by an Arabian leopard in Jabal Samhan.

Three males (M3, M4 & M5) and two females (F3 & F4) made regular journeys through Wadi Arah. M3 was present throughout the study, occurring on average every 26 days, and although most records were in Wadi Arah he journeyed south to Arkak, and one of the temporary camera-traps showed that he also moved further north in October and November 1998. M4 was recorded regularly in Wadi Arah during the first months of the study; his use of trails overlapped with M3, and both were photographed squat defecating and scent spraying. However, on only one occasion were both recorded on the same day. On 2 December 1997 records at two camera-traps and video camera-trap footage (Spalton & Willis, 1999) showed M3 in aggressive pursuit of M4. Although M5 was mostly recorded in Arkak he started to journey into Wadi Arah in December 1999. His visits were usually separated by on average 9 days from those of M3 but on two occasions they were in the area on the same day. F3 and F4 were recorded in Wadi Arah from the start of the study to May 1999 but on only 10 and seven occasions, respectively, during this first period. After May 1999 F3 was only recorded once. F4 continued to occasionally visit but was not recorded after May 2000.

M5 was recorded regularly at Arkak, passing through the area on 29 occasions, on average every 46 days, ascending and descending the escarpment on nine occasions. The maximum distance he was known to move was 7.7 km. Two males (M3 & M4) and two females (F3 & F4) from Wadi Arah were recorded infrequently in Arkak. There were one and three records in Arkak, respectively, for F5 and F6, which were not recorded subsequently or elsewhere. A sub-adult female (F9), estimated to be aged 8 months, was photographed twice in 2000.

Temporary camera-trap 1, 20 km north of Wadi Arah, recorded M3 and F3. On 3 October 1998 F7 was photographed at camera trap 1 accompanied by M3; the only record of a male and female together. F7 was also photographed at camera-trap 2 but not elsewhere in the study area. Camera-traps 3 and 4, in two wadis in the north-east of the Reserve, did not record leopards.

Leopards were most active at 02.00–07.00 and least active at 12.00–15.00 (Fig. 2). All sites showed this general pattern but overall activity in Wadi Rabkhut was significantly different from the other two sites ($\chi^2 = 9.976$, $P = 0.002$) with two clearly defined peaks, at 06.00–09.00 and 15.00–19.00, with 70% of records during daylight hours. In Wadi Arah and Arkak peaks of activity

Table 1 Temporal presence of the 17 photo-trapped leopards during the study period (September 1997–November 2000).

	1997				1998												1999												2000									
Individuals	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Females																																							
F1					+	+	+	+	+	+	+			+		+	+																					
F2															+				+			+	+	+					+				+		+	+		
F3		+					+	+	+	+			+	+	+	+		+				+		+														
F4							+	+	+	+			+							+			+				+						+	+				
F5											+						+																					
F6																	+																					
F7												+	+	+	+	+																						
F8																					+																	
F9																															+		+						
Males																																						
M1		+				+		+		+	+	+	+	+	+																						
M2																		+	+	+				+				+										
M3		+		+		+	+						+	+	+	+	+		+	+		+	+	+		+			+	+	+		+		+		+	
M4		+		+		+	+	+	+	+																												
M5																					+		+	+	+			+	+	+	+	+		+	+	+	+	+	+
Unknown sex																																						
U1												+																										
U2																+																						
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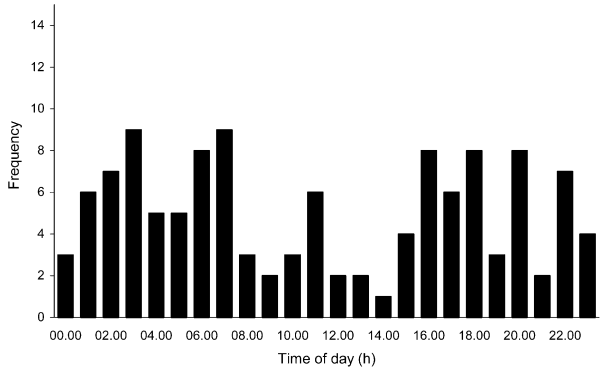

Fig. 2 Activity times of all leopards (Table 1) combined, as the number of camera-trap photographs in each hour.

were less marked and only 40% were daytime records. Although there was less activity during 10.00–15.00 in the summer months (April–September) there was no difference in activity times compared to winter (October–March) for the three sites combined or any site alone ($\chi^2 = 1.374$, P = 0.241).

Other wildlife species

Camera-traps also recorded 13 other species of mammal (Table 2). Blanford's fox *Vulpes cana* was the most commonly recorded canid (56% of carnivore records). In Arkak it was recorded from July 1998 to April 1999, but after May 1999 it seems to have been replaced by the red fox *Vulpes vulpes*. Arabian wolves *Canis lupus arabs*, mostly nocturnal, were usually recorded alone but a pair was recorded in Wadi Rabkhut and a group of three at Arkak. The striped hyaena *Hyaena hyaena sultana* was always solitary and almost exclusively nocturnal. The African small-spotted genet *Genetta felina grantii* and white-tailed mongoose *Ichneumia albicauda albicauda* were recorded on a few nights. The honey badger *Mellivora capensis pumilio* was also nocturnal and recorded alone and in pairs. There was a single record of an Indian crested porcupine *Hystrix indica* descending the escarpment at Arkak in 2000. Nubian ibex *Capra ibex nubiana* accounted for 58% of non-carnivore species recorded and was most commonly recorded in Wadi Rabkhut; they were also recorded at Arkak but did not descend the escarpment. The Arabian gazelle *Gazella gazella cora* was only recorded on the mountaintop at Arkak and, like the ibex, was diurnal.

Human activities

Shepherds with either goats (n=41) or camels (n=56) were recorded at Arkak. Most records were of 1–3 men

Table 2 Number of separate photographs of the 14 mammal species recorded by camera-traps (Fig. 1) in Jabal Samhan, Oman, with their global and national Red List status.

	Sites			Red List category (criteria)	
Species, by Order & Family	Rabkhut	Arah	Arkak	Global[1]	Oman[2]
Carnivora, Felidae					
Arabian leopard *Panthera pardus nimr*	90	106	41	CR (C2a)	CR(C2a)
Wildcat *Felis silvestris gordoni*[3]	2	0	2		DD
Carnivora, Canidae					
Arabian wolf *Canis lupus arabs*[3]	1	0	44		EN(C2a)
Blanford's fox *Vulpes cana*	6	10	128	VU(C1)	DD
Red fox *Vulpes vulpes*[3]	0	0	19		
Carnivora, Hyaenidae					
Striped hyeana *Hyaena hyaena sultana*[3]	16	0	6	LR/nt	CR(C2a)
Carnivora, Mustelidae					
Honey badger *Mellivora capensis pumilio*[3]	1	5	4		DD
Carnivora, Viverridae					
African small-spotted genet *Genetta felina grantii*[3]	2	1	0		DD
White-tailed mongoose *Ichneumia albicauda albicauda*	1	2	5		DD
Artiodactyla, Bovidae					
Nubian ibex *Capra ibex nubiana*	40	30	15	EN(C2a)	EN(C2a)
Arabian gazelle *Gazella gazella cora*[3]	0	0	30	VU(C1)	LR/cd
Hyracoida, Procavidae					
Rock hyrax *Procavia capensis jayakari*[3]	2	28	3		DD
Rodentia, Hystricidae					
Indian crested porcupine *Hystrix indica*[3]	0	0	1		DD
Insectivora, Erinaceidae					
Ethiopian hedgehog *Paraechinus aethiopicus*[3]	0	0	42		

[1]IUCN (2006)
[2]Fisher (1999)
[3]New record for Jabal Samhan

with <20 camels ascending the escarpment after the summer monsoon or after heavy cyclonic rainfall. On three other occasions family groups accompanied camels and goats. The shepherds, who usually live on the lower slopes of the escarpment, established temporary camps for up to 3 months to exploit new grazing. They did not enter Wadi Arah but preferred the high mountain and upper escarpment. In Wadi Rabkhut 1–2 shepherds, without stock, were recorded on six occasions in February and June 2000, and there were occasional records of 2–8 camels but never smaller livestock.

Frankincense harvesters, usually 1–4 men, were first recorded in December 1997 in Wadi Arah but were not recorded in Wadi Rabkhut or Arkak. After some early interest in the camera-traps the harvesters generally avoided all camera-traps. In March 1998 harvesters established a small camp at a water seepage in Wadi Arah where they were regularly encountered in all months of the year. Conversations with the frankincense harvesters revealed that they recognized some leopard signs (e.g. calling). We found no evidence that they tried to kill leopards although there was evidence of them trapping birds and on one occasion killing and taking a pregnant female ibex. Donkeys, used by frankincense harvesters, were recorded in all months, with 76% of records in October–February.

Discussion

Leopard

The Arabian leopard, like other species of leopard, appears to be solitary and to move within a home range, an area with which they are familiar and that is characterized by a network of travel routes (Bailey, 1993). In Jabal Samhan these routes are marked by scent marks, including scrapes, deposition of faeces, urine spraying and cheek rubbing (Spalton & Willis, 1999). Use of trails in Wadi Rabkhut was exclusive, whereas in Wadi Arah there was some range sharing between adult males and between adult females. No male-male or female-female overlap is known in African savannah habitat (Mizutani & Jewell, 1998) whereas elsewhere overlap, especially in female ranges, is common (Bailey, 1993; Stander *et al.*, 1997). However, although there was spatial overlap of both sexes in Jabal Samhan there was little evidence of temporal overlap. Like leopards in the Kalahari (Bothma & Le Riche, 1990) and snow leopards in Nepal (Jackson & Ahlborn, 1989) males and females avoided each other, presumably by staggering activities in different parts of shared ranges. The extensive scent marking is presumably the key activity that allows overlap with minimal direct encounters while also enabling animals to come together for breeding.

The main reason for spatial sharing is probably the steep topography of the gorges, which requires individual leopards to use the same travel corridors into prey rich areas and to access water. In many areas there was only one trail used by leopard, ungulates and frankincense harvesters alike. As Stander *et al.* (1997) suggested for leopards in arid northern Namibia where overlap between males and between females was extensive, the energetic costs of large ranges and long daily movements may prevent individuals from maintaining exclusive ranges.

Some individual leopards were only recorded 1–3 times. These animals may have been subadults whose ranges can be expected to overlap those of adults. Bailey (1993) found that subadult females stayed in their natal ranges but made exploratory movements elsewhere, whereas subadult males had unstable home ranges and explored over vast areas.

The leopard is widely considered to be a nocturnal species (Bailey, 1993; Jenny, 1996; Stander *et al.*, 1997). In Wadi Arah and on the escarpment the leopards were mostly nocturnal but in Wadi Rabkhut they were mainly diurnal. One explanation may be the nature of habitat in Wadi Rabkhut, where there is permanent water and the steep-sided wadis give late shade in the morning and early shade in the afternoon; for much of the day leopards do not face conditions of high temperatures and water loss. However, the most obvious difference between Wadi Rabkhut and the other two areas was the virtual absence of human activity; frankincense harvesters were active in Wadi Arah and shepherds and their flocks at Arkak. Leopards are known to avoid humans, at least in daytime (Bailey, 1993).

As in other large canids such as lions (Schaller, 1972) and leopards (Bailey, 1993) in Africa the leopards exhibited two daily peaks in activity, avoiding the midday heat when winter and summer shade maximums typically reach 30 and 45°C, respectively. High temperatures are considered to inhibit leopards' movements and they adjust their activity to overlap with periods of cool temperatures (Bothma & Le Riche, 1994).

Other wildlife species

Records of other mammal species confirmed the continuing presence of three Oman Red List species and revealed the presence of nine others, all new records for Jabal Samhan but previously recorded elsewhere in southern Oman (Harrison & Bates, 1991). The number of large mammal species is highest at Arkak where primary productivity is high along the escarpment. Whereas both the wolf and hyaena occurred alongside leopards in Wadi Rabkhut and Arkak, neither was recorded in Wadi Arah in spite of the area having abundant water and potential

prey species. The hyaena is known to scavenge around human settlements (Mills & Hofer, 1998) and the wolf will take human garbage (Salvador & Abad, 1987) and thus may prefer areas closer to settlements. The red fox has been recorded displacing the smaller Ruppell's fox *Vulpes ruppelli* around human settlements elsewhere in Oman (Spalton, 2002). Its presence on the escarpment after April 1999, apparently replacing Blanford's fox, follows the same pattern. Nubian ibex are the most common ungulates on Jabal Samhan. A provisional investigation of 74 leopard scats collected during this study confirmed the importance of ibex, gazelle and, to a lesser extent, hyrax, in the leopard's diet (Muir Wright, 1999).

Human activities

Seasonal movements onto the mountain by small numbers of people should not be incompatible with the management of the Reserve. Unlike some large carnivore species the leopard seems to have a high tolerance of people (Woodroffe, 2000). No cases of leopards killing livestock were documented during the study and scats did not containg goat or camel hair (Muir Wright, 1999). However, since the survey, leopards are known to have killed goats and young camels on six occasions, and in one case a local person shot and killed a leopard (J.A. Spalton, pers. obs.). Leopards are probably often blamed for kills by wolves and for livestock losses where no clear cause can be identified.

The impact of the frankincense harvesters on the leopards is difficult to assess but they may have caused them to become increasingly nocturnal. The practice of allowing donkeys to breed and roam free has heavily affected the vegetation of Jabal Samhan and there is a danger that feral donkey populations will establish and compete with wild ungulates for the limited water and grazing resources. Frankincense has been harvested in Dhofar since the times of the Pharaohs (Groom, 1981) and banning the practice in the Reserve would be counterproductive. However, necessary controls and monitoring mechanisms must be put in place or damage to the habitat will continue and frankincense trees may be lost to overharvesting.

Conclusions

Our survey has provided the first evidence that a breeding population of the Arabian subspecies of leopard survives in the Arabian Peninsula. Given that leopards in Yemen are under threat from trade and that good evidence of surviving populations in other range states is lacking (EPAA, 2003), except for a small population in Israel (Perez *et al.*, 2006), this population may be one of the last on the Peninsula. The viability of the leopards of Jabal Samhan not only depends on population size, however, but on the degree of isolation from other populations or subpopulations. Camera-trap records of leopards in Jabal Qamar in 2003 (J.A. Spalton, unpubl. data) raises the possibility that the leopard population of Jabal Samhan may not be closed but part of a population that extends west to the Oman-Yemen border. However, the new records also indicate that these areas support fewer leopards than Jabal Samhan.

Jabal Samhan probably represents the last opportunity to conserve the Arabian leopard in the wild. The leopard's prey base appears to be intact, the Reserve is large, there is no permanent human habitation and wildlife rangers, recruited locally, are active in parts of the Reserve. However, the issue of conflict between shepherds and leopards needs to be addressed and controls are needed to prevent further damage by frankincense harvesters. The completion of a coastal road from Hadbin to Hasik in 2005 will make parts of the reserve more accessible, necessitating stronger enforcement of regulations concerning access. Managers also need to be mindful of the potential threat of illegal regional trade in wild animals (Spalton *et al.*, 1999).

Conserving the Arabian leopard for its own sake is not likely to be sufficient incentive for local communities, who still regard leopards as a threat to themselves, their families and their livelihoods. More research to understand these issues in the area is required but the main challenge is to create new and innovative opportunities that will bring economic benefit to the communities that live in and around Jabal Samhan.

Acknowledgements

The Arabian Leopard Survey, supported by His Majesty Sultan Qaboos bin Said, is funded by the Diwan of Royal Court of the Government of the Sultanate of Oman. We particularly thank the helicopter pilots and crews of the Royal Flight of Oman and the Royal Air Force of Oman for their excellent support.

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