Habitat preferences by the Persian Leopard (*Panthera pardus saxicolor* Pocock, 1927) in Armenia

by Igor Khorozyan

Abstract. This paper describes and discusses the results of a study which combined Geographical Information System (GIS) mapping and statistical analysis of the spatial distribution of the Persian Leopard *Panthera pardus saxicolor* presence signs (latrines and tracks) and the key human activities (villages, roads and livestock breeding) in the principal protected area of Armenia, Khosrov Reserve, and its wildlife corridor, Gndasar Mt./Noravank Canyon area. The critical habitat for the Leopard in the Khosrov Reserve is sparse juniper forest. Human activities are least intense in the Khosrov Reserve area, where all the villages are abandoned but are used as summer pastures for livestock. On the other hand, the Gndasar Mt./Noravank Canyon area contains high highway density and 13 inhabited villages with high human and livestock numbers. Livestock grazing should be carefully controlled for Leopard conservation, since this cat's range and livestock areas overlap. The Gndasar Mt./Noravank Canyon area provides a vital movement corridor for the Leopards and other wildlife between Khosrov Reserve and southern Armenia, and also with northern Iran where significant numbers of Leopards live. Based on the spatial information we provide, we give a list of urgent recommendations for Leopard conservation measures in the study area.

Kurzfassung. In dieser Arbeit werden die Ergebnisse einer Untersuchung zur Habitatpräferenz des Persischen Leoparden, *Panthera pardus saxicolor*, im bedeutendsten Schutzgebiet Armeniens, dem Khosrov-Reservat, und dessen „Wildlife-Korridor", dem Gebiet des Gndasar Mt./Noravank Canyon vorgestellt. Dabei werden Kartierungen unter Zuhilfenahme von Geographischen Informationssystemen (GIS) mit einer statistischen Analyse der räumlichen Verteilung von Anwesenheitsanzeichen von Leoparden (Spuren und Latrinen) mit den hauptsächlichen menschlichen Einflüssen (Dörfer; Straßen, Haustiere) kombiniert. Der kritische Habitat für den Leoparden im Khosrov-Reservat sind lockere Wacholderwälder. Die menschlichen Einflüsse sind im Khosrov-Reservat am geringsten; die Dörfer sind dort nicht mehr permanent besiedelt, sondern dienen nur noch im Sommer als Almweide. Im Gegensatz dazu hat das Gebiet Gndasar Mt./Noravank Canyon eine sehr hohe Straßendichte und 13 ständig bewohnte Dörfer mit einer hohen Einwohnerzahl und einem hohen Viehbestand. Die Beweidung sollte daher im Hinblick auf den Schutz des Leoparden sorgfältig kontrolliert werden, da sich die Reviere der Leoparden mit den Weidegebieten der Haustiere überlappen. Das Gebiet Gndasar Mt./Noravank Canyon dient als wichtiger Korridor für den Leoparden und andere Wildtiere zwischen dem Khosrov-Reservat und Süd-Armenien und weiter hin zum Nordiran, wo noch eine bedeutende Leoparden-Population existiert. Basierend auf den räumlichen Informationen wird eine Liste von Empfehlungen für den Schutz des Leoparden im Untersuchungsgebiet gegeben.

Key words. Geographical Information System, GIS, Leopard, conservation, space, habitat

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Introduction

The large predators and especially big cats are classic examples of species which exist at naturally low densities over vast areas, become rare and endangered in many regions, and whose research and conservation using traditional approaches are desperately difficult and often unsuccessful (NOWELL & JACKSON 1996). The principal factor making the big cats prone to local rarity and even extinction is their conflict with rural people for space, e.g. the "edge effect", defined as the increased chances of carnivores to be shot along the border of the protected area which is surrounded by hostile agricultural lands and is quantitatively estimated as high reserve perimeter/area ratios (WOODROFFE & GINSBERG 1998).

In the light of this, the combined use of non-invasive methods and the Geographical Information System (GIS) should serve as an indispensable conservation tool relying on such issues as habitat distribution and selective use by carnivores, human activities beyond and within the species' distribution area, and others (AKÇAKAYA 1994, BALL 1994, FAUST & TILSON 1992, STITH & KUMAR 2002).

In this paper, we consider the usefulness and efficiency of such a combined application for the benefits of the conservation of rare and cryptic large predators, using the case study of the endangered Persian Leopard *Panthera pardus saxicolor* population in two areas of Armenia: 1. Khosrov Reserve (40°07'N, 44°44'E – 40°02'N, 45°02'E), the premier protected area in the country and 2. Gndasar Mt./Noravank Canyon area (39°52'N, 45°09'E – 39°40'N, 45°13'E) to the south-east of Khosrov Reserve, which provides the vital Leopard corridor between this protected area and southern Armenia and further onto northern Iran (LUKAREVSKY 2001a; Fig. 1). Being the rarest and most charismatic representative of the national mammalian fauna listed as "endangered" in the Armenian Red Data Book and in the 2002 IUCN List of Threatened Species, this carnivore ideally fits the criteria elaborated for setting the national wildlife species conservation priorities under conditions of global financial uncertainties (SUTHERLAND 2000).

No scientifically-based estimate of population size is known for the Leopard in Armenia, but it certainly does not exceed 10–20 individuals roaming from Khosrov Reserve down to the Armenian-Iranian border (Fig. 1). The key factors determining the low Leopard density in the country are the narrow prey base (mainly Bezoar Goat, *Capra aegagrus*), habitat use by people, poaching and wild fire (KHOROZYAN & MALKHASYAN 2002).

Material and methods

The non-invasive study of habitat use by local Leopards was confined to analysis of the spatial distribution of their presence signs (latrines and tracks) which were recorded and collected during monthly field trips in 2001–2002. The Leopard latrines were positively identified on the basis of their characteristic "segmented" shape with a mean diameter approx. 2.7 cm (range 2.0–3.0 cm), pointed ends, many lobes and the place of scat deposit (propensity to use trails along the ridge tops and to mark them with scats when travelling) (KHOROZYAN & MALKHASYAN 2002). We used the following sex-related differences in Persian Leopard track size: track width 8.0–9.5 cm in adult males, 6.0–7.5 cm in adult females and 5.0-7.0 cm in subadults (LUKAREVSKY 2001b). In total, 26 latrine sites and 5 track sites were found and mapped by us.

Our GIS map was produced by means of ArcView 3.1 and 3.2a packages (Environmental Systems Research Institute, Inc., USA) on the basis of the digitized electronic version of the topographic map of Armenia made by WS Atkins Environment, UK in 2001 (cartographic layers – reserve borders, roads [highways and dirt roads], forests and crop lands, and settlements

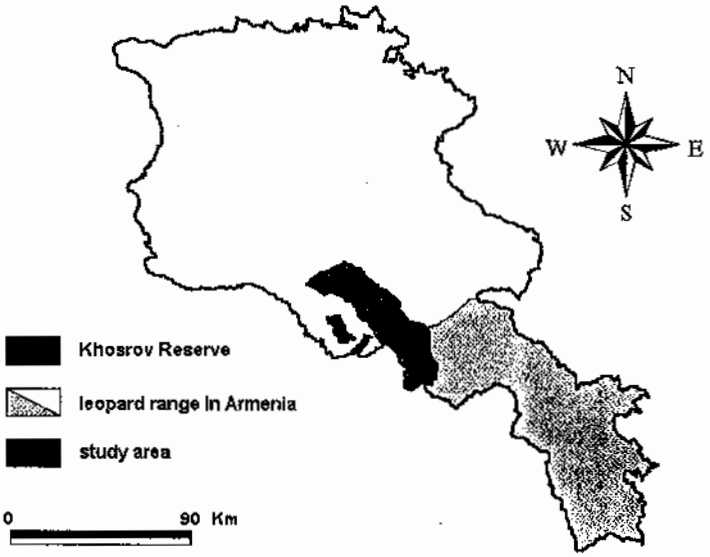

Fig. 1. The map of the Leopard *Panthera pardus* distribution and our study area in Armenia.

Tab. 1. Distribution of landscape belts in the Khosrov Reserve and Gndasar Mt./Noravank Canyon areas within the Leopard *(Panthera pardus)* range in Armenia.

Landscape belt	Elevation gradients, m	Khosrov Reserve area				Gndasar Mt. / Noravank Canyon area	
		Total		Protected area			
		Area, km^2	%	Area, km^2	%	Area, km^2	%
Semi-desert	800-1200	22.6	2.9	-	-	-	-
Arid grassland	1200-1600	173.8	22.1	-	-	89.6	16.6
Sparse forest	1400-2300	139.6	17.8	124.2	79.4	-	-
Mountainous grassland	1600-2300	225.8	28.8	30.0	19.2	388.8	71.8
Subalpine grassland	2200-2600	180.0	22.9	1.4	0.9	62.8	11.6
Alpine grassland	2600-2800	33.4	4.3	0.8	0.5	-	-
Nival zone	2800-3200	9.3	1.2	-	-	-	-
Total	800-3200	784.5	100.0	156.4	100.0	541.2	100.0

[inhabited and abandoned]). POGHOSYAN (1990) was the source for mapping the landscape belts through elevation gradients (Tab. 1). The layers of Leopard latrines, Leopard tracks, Leopard track sets, Leopard range, reserve infrastructure, shepherd camps, road posts, fish farms, bee hives and poultry farms were created following field determination of the position fixes of the objects in question by handheld Magellan 310 GPS Satellite Navigator. So our GIS map contained 15 cartographic layers coming from field surveys and external sources as described

Leopard habitat in the Meghri region, Siunik Province, southern Armenia, comprising cliffy ridge tops covered by sparse juniper forests.

elsewhere (STITH & KUMAR 2002). The quantitative information provided in Tabs. 1 and 4 was obtained directly through the GIS measurement tools. The Jacobs' habitat preference index D was calculated as in SUTHERLAND (2000): $D = (r - p) / (r + p - 2rp)$, where r is the ratio of the number of Leopard latrines found in a specific landscape belt to the number of all Leopard latrines found in all belts, and p is the ratio of the area of a specific landscape belt where the given latrines are found to the area of all belts within the Leopard range. D changes from –1 (always ignored) through 0 (indifference) to +1 (restricted to that habitat). The landscape belt having the highest value of D was identified as the critical habitat (MAEHR 1997). The Leopard range was identified and measured as the area encompassing all the latrine and track sites found by us, as well as the recent and current Leopard sightings documented by KHOROZYAN (1999, 2001). Only data from the Khosrov Reserve area were sufficient enough to be used in this analysis (n = 20).

Statistical information on the rural people, livestock and pastures shown in Tab. 2 was kindly provided by the following municipal bodies: Vayots Dzor Province Authority - Department of Agriculture; Ararat Province Authority - Ararat Department of Statistics and State Registry; Syunik Province Authority - Department of Urban Construction, Department of Agriculture and Conservation and Department of Land Use.

The statistical significance of region-to-region differences in agricultural data (Tab. 2) and spatial separation between Leopards and people (Tab. 3) and all other data-processing procedures were performed in SPSS 9.0 for Windows software package.

Results

Distribution and Selective Use of Habitats

As shown in Fig. 1, the Leopard range in Armenia encompasses a vast region from Khosrov Reserve's three districts through the corridor of Gndasar Mt./Noravank Canyon area to all of southern Armenia which, in its turn, is connected to northern Iran, where a significant

Tab. 2. Some agricultural statistics describing the most important human activities in the study areas as compared to the background area (southern Armenia – Kapan and Meghri regions). SL = small livestock (sheep + goats), P = pasture. – [1]Calculated as the product of mean values 3 people/household for 5 households per abandoned village as estimated from our field experience. – [2]These ranges of estimates are based on the rural population estimate given above and on the following minimum and maximum ratios of livestock heads per capita calculated for villages in the Gndasar Mt./Noravank Canyon area: 0.21-1.04 for cattle, 0.05-2.16 for sheep and 0.06-0.76 for goats.

Parameter	Gndasar Mt./Noravank Canyon area (n = 13)	Khosrov Reserve area (n = 10)	Southern Armenia (n = 46)
Population/village	1226.5 ± 181.0	15[1]	237.3 ± 29.3
Cattle No./village	568.6 ± 93.2	3.2-15.6[2]	135.8 ± 18.6
SL No./village	701.8 ± 138.5	1.6-43.8[2]	219.5 ± 27.7
Total livestock No./village	1285.7 ± 215.9	4.8-59.4[2]	355.3 ± 40.1
% cattle/village	45.4 ± 4.6	unknown	39.5 ± 3.1
% SL/village	54.6 ± 4.6	unknown	60.5 ± 3.1
P area/village, km^2	7.4 ± 1.3	unknown	4.8 ± 1.2
Cattle dens./village, No./ha P	1.3 ± 0.4	unknown	0.9 ± 0.2
SL dens./village, No./ha P	1.3 ± 0.4	unknown	1.3 ± 0.2
Total livestock dens./village, No./ha P	2.7 ± 0.7	unknown	2.2 ± 0.4

portion of the Leopard population exists (KIABI et al. 2002). The Khosrov Reserve area and Gndasar Mt./Noravank Canyon have completely different landscape structures, principally marked by the domination of sparse forests in the former area and their absence in the latter (Tab. 1 and Fig. 2).

The critical habitat is "the specific area within the geographical area occupied by the species in which are found those physical or biological features (1) which are essential for the conservation of the species and (2) which may require special management considerations or protection" (MAEHR 1997). For the Leopard in Khosrov Reserve, the critical habitat is the sparse forest (Fig. 3) with precipitous and often inaccessible cliffy massifs where the dominant plant species are evergreen junipers, *Juniperus* spp., and, to a lesser extent, deciduous Almond, *Amygdalus fenzeliana*, and pears, *Pyrus* spp. This is not a typical forest as people usually perceive it: the trees are crooked and stand at a distance from each other, never forming closed canopy. The cliffs are used by Leopards for rest, for preying on the Bezoar Goats and opportunistically on European Hares, *Lepus europaeus*, and for breeding (KHOROZYAN & MALKHASYAN 2002). This landscape is found along the ridge tops where the Leopards find optimal straightforward trails to move through the vast territories for quite a short time and where they can easily spot prey grazing beneath from their vantage watch posts on the cliff edges. Towards the canyon bottom, with streams flowing alongside, this sparse forest changes into dense "jungles" or true woods consisting of oak, *Quercus macranthera*, Oriental Beech, *Fagus orientalis*, crooked and thorny berry trees and shrubs like Buckthorn, *Rhamnus pallasii*, Dog Rose, *Rosa canina*, Hawthorn, *Crataegus calycina*, Wayfaring Tree, *Viburnum lantana*, etc., and where the dominant large mammals are Brown Bear, *Ursus*

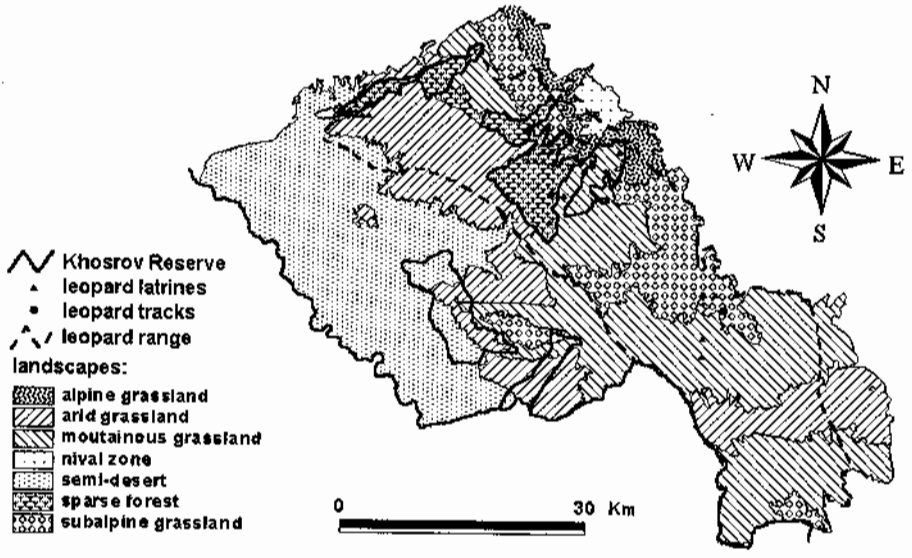

Fig. 2. Distribution of Leopard latrines and landscape belts in Khosrov Reserve and Gndasar Mt./Noravank Canyon areas.

arctos, and Wild Boar, *Sus scrofa*. Other habitats where we found the Leopard scats (arid, mountainous and subalpine grasslands) are seemingly used opportunistically by local Leopards and only for movements between the blocks of the sparse forest. Semi-deserts, alpine grasslands and the nival zone are definitely ignored by local Leopards.

Information on habitat use by the Leopard in Gndasar Mt./Noravank Canyon area was too scanty as only 6 latrines were found by us and we refrain from drawing any conclusions.

Human Activities in the Habitats

The principal kinds of human activities within the study areas mapped and quantified by us are villages, livestock breeding and, in certain areas, roads (Tab. 2 and Fig. 4). The Gndasar Mt./Noravank Canyon area has much higher values of population, livestock numbers and pasture areas per village than southern Armenia (a background area with the minimum of human density and animal husbandry) and Khosrov Reserve, with significance levels of difference at least $p < 0.05$ (Tab. 2). However, livestock densities per ha of pasture are similar in Gndasar Mt./Noravank Canyon area and in southern Armenia, deriving from the balance of high livestock numbers in the former area and small pasture areas in the latter.

The highway density is more than twice as much in Gndasar Mt./Noravank Canyon (0.14 km^{-1}) than in the Khosrov Reserve area (0.06 km^{-1}), but the dirt road densities are almost equal (0.35 and 0.38 km^{-1}, respectively).

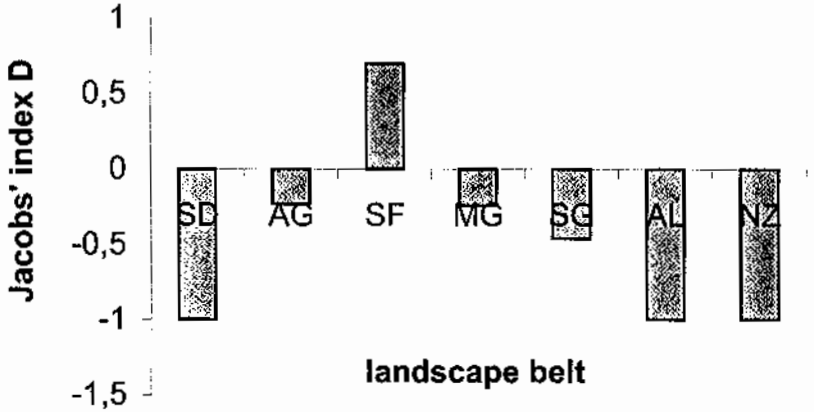

Fig. 3. Distribution of Jacobs' habitat preference index *D* for *Panthera pardus* over the landscape belts in Khosrov Reserve. Abbreviations: SD – semi-desert, AG – arid grassland, SF – sparse forest, MG – mountainous grassland, SG – subalpine grassland, AL – alpine grassland, NZ – nival zone.

Tab. 3. Altitudinal separation of Leopard signs and human sources in Khosrov Reserve and Gndasar Mt./Noravank Canyon areas. Abbreviations: T – tracks, S – scats, RI-RP – reserve infrastructure and road posts, ShC – shepherd camps, NS – difference is statistically non-significant. The 95% confidence intervals are given for the difference of sample means.

Pairs of compared samples	Area	95% confidence intervals
Leopard T and S vs. RI-RP	central Khosrov Reserve	417.8-804.4 m, $df = 15$, $p < 0.001$
Leopard S vs. ShC	eastern Khosrov Reserve	NS
Leopard S vs. RI-RP	eastern Khosrov Reserve	333.2-1,090.6 m, $df = 12$, $p < 0.05$
Leopard T and S vs. ShC	Gndasar Mt./Noravank Canyon	NS

Tab. 4. The "edge effect" in Khosrov Reserve as measured by the reserve perimeter/area ratio. The "edge effect" ranking: H – high, M – medium.

Reserve district	Reserve perimeter, km	Reserve area, km^2	Perimeter/ area ratio, km^{-1}	"Edge effect" ranking
Garni, N Khosrov	46.3	33.1	1.40	H
Khachadzor, E Khosrov	39.1	30.9	1.26	H
Urtsadzor, S Khosrov	31.8	25.7	1.24	H
Khosrov, central Khosrov	82.7	92.4	0.89	H
Western	49.1	76.5	0.64	M
Total	249.0	258.6	0.96	H

Leopard habitat in the Meghri region, Siunik Province, southern Armenia.

Leopards live at higher elevations, more precisely 300–1000 m higher, than do the reserve staff and this difference is statistically significant: the mean elevation of the occurrence of Leopard latrines and tracks is 2164.5 m (n = 8, SD = 348.1) in eastern Khosrov Reserve and 2074.0 m (n = 7, SD = 154.0) in central Khosrov Reserve, whereas local reserve infrastructure and road posts are located at means of 1528.1 m (n = 6, SD = 141.9) and 1442.0 m (n = 10, SD = 244.0), respectively. However, the elevations of Leopard signs and shepherd camps (mean 2008.5 m, n = 11, SD = 384.0) are similar, implying their co-existence and range overlaps which has significant conservation implications (Tab. 3). The signs and camps are located on average at 1878.1 m (n = 24, SD = 427.4) and 1820.6 m (n = 5, SD = 484.0) in the Khosrov Reserve area and at 2563.0 m (n = 7, SD = 276.8) and 2165.0 m (n = 6, SD = 145.8) in the Gndasar Mt./Noravank Canyon area.

Fish farms, bee hives and poultry farms are not numerous in our study area (3, 3 and 1) and are confined to lower riparian lands where the Leopards do not occur. So we have excluded them from our analysis.

Edge Effect

The "edge effect" is medium to high in Khosrov Reserve and is high in all three districts where the Leopards live (Garni, Khachadzor and Khosrov) (Tab. 4).

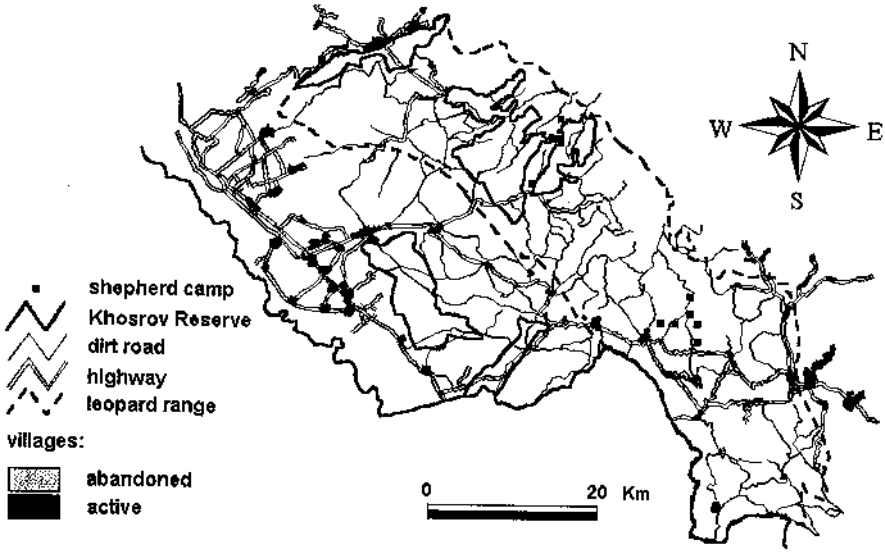

Fig. 4. Villages, road network and shepherd camps in Khosrov Reserve and Gndasar Mt./Noravank Canyon areas.

Discussion

The sparse juniper forest has been the critical habitat for Leopards in the Khosrov Reserve (Figs. 2, 3). This requires specific landscape-oriented conservation measures, such as control of wild fire, which may occur in dry summer conditions in the xerophilic vegetation of this habitat through human neglect. The reserve directorate and rangers do their best to prevent and fight fires, but remoteness, complicated relief and limited logistic capacity still make this environmental hazard a possibility.

Human population is scarce in and around the Khosrov Reserve (Tab. 2) because the local villages were once inhabited by ethnic Azerbaijani who fled in the early 1990s during the Armenian-Azerbaijani military conflict over Nagorno Karabakh. All ten villages located in the Khosrov Reserve area (including two inside the protected area) are standing abandoned (Fig. 4), but they are used in the spring-autumn season as summer pastures for livestock. Despite this, the reserve accommodates a human density four times higher (32.0 individuals/100 km^2) than in a sample of 93 protected areas in the world's developing countries (mean 8.9 individuals/100 km^2) (BRUNER et al. 2001). At the same time, this seems insignificant against the background of very high human density in Ararat Province, where the Khosrov Reserve is located (14,400 individuals/100 km^2).

Since local animal husbandry is not properly managed, we do not know the pasture areas per village in this area and can only estimate that their total area exceeds 10.6 km^2 in the two principal pasture grounds (Jringol, 7.6 km^2 and Almalah, 3.0 km^2) commonly shared among several villages and located in the eastern part of the reserve.

The leopard seats and scrape in southern Armenia, August 2003.

The Khosrov Reserve area contains half the highway density of Gndasar M./Noravank Canyon area, but the dirt road densities are similar in both areas. However, in the latter area the dirt roads are in much better condition and thus more destructive to the environment than in the Khosrov Reserve area because of their frequent and intense use by the rather numerous rural population (2946 individuals/100 km^2). By contrast, in the Khosrov Reserve area the dirt roads are used mainly by people on horseback and only seldom by off-road vehicles.

Human pressures are thus minimal in the Khosrov Reserve area, which cannot be said about the Gndasar Mt./Noravank Canyon area. Its 13 villages contain many people, with livestock and their own significant pasture areas for animal husbandry (Tab. 2). The high highway density with intensive traffic in this area is caused by the presence of a highway of national strategic importance, linking Armenia's capital Yerevan with southern Armenia and further with Iran. The newly-constructed highway along the bottom of the Noravank Canyon provides access to a favorite local tourist destination, the Noravank Monastery complex of the 12^{th} century.

Wildlife, including the Leopards, frequently cross this highway in the places where the mountains come close to it, and even anti-landslide barriers built along the road do not pose a serious obstacle to some species. Gndasar Mt./Noravank Canyon area thus plays a crucial role as a wildlife corridor for mobile species and especially for the Leopards which disperse in order to establish their own land tenures through this conduit, but we are seriously concerned over the long-term capacity of this area to serve a corridor due to significant human impact. We hold several records of sightings of highway-crossing Leopards by car drivers, but do not know how significant is the effect of road collisions on the Leopard population viability. Road kills are known to be the principal mortality factor for the Leopard in Golestan National Park in Iran (KIABI et al. 2002) and for other wild cat species living in hu-

man-dominated landscapes: Iberian Lynx, *Lynx pardinus*, Tiger, *Panthera tigris*, and Eurasian lynx, *Lynx lynx* (GOODRICH et al. 2002, PALMA et al. 1999, SCHADT et al. 2002).

There is a strong separation between the Leopard occurrence and human sources, but the Leopard ranges and livestock breeding areas overlap (Tab. 3). This fact should direct our careful attention to the structure of local animal husbandry, and the first attempt to describe it in any detail is given above.

The role of the Gndasar Mt./Noravank Canyon area as a corridor is hard to overestimate, since it ensures an exchange of individuals which strengthens the Leopard population viability in the Khosrov Reserve. However, the total coverage of two these areas (1325.7 km^2, Tab. 1) is insufficient for sustaining a viable Leopard population. According to SMALLWOOD (2001), Leopard populations show reliable statistical relationship of lg (density/100 km^2) = -1.02 lg (threshold area, km^2) + 3.74 (r^2 = 0.87, $p<0.0001$), where the threshold area is the minimum area of high-quality habitat capable of supporting a viable population of a particular species. Our database on Leopard densities in Asia and Africa gives the mean of the threshold area for the Leopard equal to 4,723±2,166 km^2 within the 95% confidence interval 205–9243 km^2. The lowest values of the threshold area for the Leopard have been reached in some of the areas of Sub-Saharan Africa and India holding high densities of this cat. As the Leopard is endangered in Armenia, we can assume that only a high to very high threshold area will be applicable to the species in this country (at least 5,000 km^2 or so).

In the light of the information given above, we suggest the following list of urgent conservation measures for saving the Leopard from extinction in the Khosrov Reserve and Gndasar Mt./Noravank Canyon areas:

- Acquisition of surrounding agricultural land for enlargement of the existing protected area and minimization of its "edge effect" (Tab. 4).
- Maintenance of Gndasar Mt./Noravank Canyon area as natural corridors linking the Khosrov Reserve with southern Armenia, through which Leopards and other wildlife can move.
- Stringent control of the status of the "buffer zones" fringing the reserve border where most of uncontrollable livestock grazing in the Khosrov Reserve area takes place.
- Control of livestock grazing and elimination of the free-roaming of domestic animals over the habitats of the Leopard and its principal local prey, the Bezoar Goat.
- Development of educational campaigns to provide local rural communities with more information about the Leopard and the environment, thus raising public awareness about the value of this carnivore for nature and people.
- Control of wild fires in the sparse juniper forests of the Khosrov Reserve.

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