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THE ROLE OF PROTECTED AREAS IN NEPAL IN MAINTAINING VIABLE POPULATIONS OF SNOW LEOPARDS

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1. INTRODUCTION

Conservation biologists, drawing upon island biogeography theory, ecological-evolutionary genetics and theoretical population modelling, have attempted to establish the limits of a minimum viable population. The urgency for defining such limits is fueled by the widening realization that the world's reservoir of wildlands are being depleted at unprecedented rates. Core populations of many wild plants and animals are being confined to protected areas, including national parks, scientific reserves, natural landmarks, natural biotic areas and other special purpose lands (Soule 1987).

Only large contiguous pieces of land - with suitable habitat - can sustain populations of large "apex" predators like the snow leopard *(Panthera uncia),* a need that is proving increasingly difficult to meet, at least within the existing array of protected areas or conservation techniques. As developing countries seek to sustain their growing human populations, so conservationists have sought to emphasize the role protected areas play in sustaining life-processes, biological diversity and cultural wealth (McNeely and Miller 1984). While innovative approaches to land management are being proposed, many biologists and government officials still argue for increasing the patchwork of reserves. How much land area must be "set aside" and how viable is this strategy, given other realities such as the legitimate needs of indigenous people sharing the same habitat? In order to succeed,
conservation plans must provide for the day-to-day necessities of people living in or near protected areas.

The conservation of snow leopard in Nepal is a case in point. Besides requiring large contiguos areas of habitat, snow leopard range is restricted to a relatively narrow alpine zone that traverses the length of the country's northern border region with Tibet (Jackson 1979).

With a range that is linear and extremely narrow in places, snow leopard populations are potentially susceptible to insular effects as a result of natural or man-made barriers. Since snow leopards appear to meet most of the criteria of "keystone species", many managers assume the presence of snow leopard is indicative of a "healthy alpine ecosystem".

There are seven existing protected natural areas (national parks, conservation areas, and hunting reserves) in the mountains of Nepal. The impetus and rationale for their establishment and the explict management goals and objectives for each area differ greatly. However, common among them all is the long-term goal to preserve unique ecosystems and protect from extinction species which help to defIDe those systems. Perhaps attracted by the aura of mystery surrounding the legendary snow leopard, park administrators are quick to cite snow leopard as a primary benefactor of protected land status.

Reliable information on the distribution and density of snow leopard are not available for most of Nepal, and the situation is not likely to improve in the foreseeable future. The censuing of snow leopard populations is fraught with difficulties: the species is rare, shy and inhabits some of the most remote and forbidding terrain on earth (Jackson and Ahlborn 1986). Field surveys, even if they could provide accurate estimates are time consuming and costly.

Therefore, we resorted to estimating population levels using a simple habitat suitability model. These data were then used to explore the following questions:

- Which (if any) of Nepal's protected areas are potentially capable of sustaining a minimum viable population of snow leopard?
- If any single park was too small, could adjacent pairs or sets of protected areas meet minimum area and habitat criteria?
- To what extent are Nepal's reserves linked by potentially suitable habitat?
- From the standpoint of conservation, what are some of the management alternatives and considerations in maintaining viable populations of snow leopard?
- What conclusions are applicable to other parts of the snow leopard's range?

2. METHODS

Using map-based variables, we delineated areas of suitable habitat for snow leopard within Nepal. The resultant habitat was then rated using a simplified Habitat Suitability Index (HSI) model (U.S. Fish and Wildlife Service 1981), developed from a 4-year study of snow leopard habitat preferences in west Nepal (Jackson and Ahlborn 1984); these values were then converted to snow leopard densities using standardized habitat suitability conversion factors. The distributional patterns of habitat and snow leopards were evaluated using PC-based Geographic Information System (GIS) software.

Our primary objective was not to distinguish between small areal differences in habitat suitability but rather to reliably differentiate non-habitat from several broad categories of increasingly suitable habitat, within parks and along intervening "corridors".

2.1. Habitat suitability determination and snow leopard population estimation.

Jackson and Ahlborn (1984) constructed a preliminary Habitat Suitability Model (HSI) for snow leopard in Nepal, using information on the cat's habitat utilization and preferences as derived from radio-telemetry (Jackson and Ahlborn 1986); marking behavior (Ahlborn and Jackson 1988), and a review of the literature. Briefly, this information indicated that snow leopard preferred non-forested, preciptious and broken terrain with scattered shrub and herbaceous cover interspersed with rocky areas (less than 10% vegetation cover). Terrain with broken cliffs and rocky outcrops (cover for snow leopard and large prey species) interspersed with relatively even-surfaced terrain (which usually constitutes higher quality foraging habitat for ungulates) appears most favorable. The best snow leopard populations tend to occur in regions supporting few permanent settlements (less than 2 - 4 per 100 km) with pastoral or trading economies, and typically involving Buddhist ethnic groups whose religion does not readily sanction the killing of wildlife.

Using 1:250,000 scale (AMS Series, US Army Mapping Agency, Washington, D.C., 1955) topographic maps (contour interval = 500 feet), we divided Nepal into square grids with dimensions of 100 km on a side. We considered potential snow leopard range to encompass lands located between 10,000 feet in elevation and the mapped permanent snow-line (situated between 17 ,000 and 19,000 feet, depending upon latitude, aspect and local terrain). Since snow leopards are recorded in a few valleys at elevations lower than 10,000 feet (Jackson 1979), these limits tend to underestimate the extent of potential habitat. However, this bias is minimal given the high human population of lands below the 10,000 foot contour, which discourages occupation by snow leopard.

The percent of potential habitat present within the grid was computed according to six cover classes:

Class 0 no (0 %) habitat is present in grid
1 trace - 10 % of grid constitutes habitat
2 10 - 25 % constitutes habitat
3 26 - 50 % constitutes habitat
451 - 75% constitutes habitat
576 - 100% constitutes habitat

All grids were rated for each of six variables (Table 1) that we judged best distinguished habitat from non-habitat for snow leopard. We assumed that map contours accurately reflected the terrain and elevation of sampled areas, that all mapped vegetated areas represented forest (i.e. unsuitable habitat for snow leopard), and that the extent of human disturbance is

directly related to the number of villages present in the area. In order to quantify village dispersion, terrain brokenness and drainage complexity, we subdivided the 100 kID grid into 16 equal-sized subgrids, and counted the number supporting the feature in question.

Table 1: Description of Habitat Suitability Variables

Variable	Measurement Method
Elevation	Percent of grid between 10,000 feet and snowline
Vegetation	Percent of grid that is non-forested and/or not covered with permanent snow fields
Land Ruggedness	Percent of grid with precipitous and heavily broken terrain
Drainage Density	Number of subgrids with mapped drainages
Human Habitations	Number of sub grids with villages and total number of villages in grid
Park Status	Percent of grid located within an existing or proposed protected area

Variables were then combined in a simple compensatory manner, in which all are given equal weighting (US Fish and Wildlife Service 1981), to derive a suitability index scaled between 0 (unsuitable) and 1.0 (optimal suitability) for each grid. Computerized analysis then assigned each grid into low, medium or high suitability, using equal-sized HSI ranges to establish limits for each of the three suitability classes. The number of snow leopards present within a particular grid was calculated by multiplying the percent of suitable habitat by the estimated density of leopards. One of four habitat suitability to density transformations was used;

sites classified as unsuitable lacked snow leopards, a value of 0.5 snow leopards per 100 kID ^{2} was used for grids with low suitability, 2.5 snow leopards per 100 kID for medium suitability grids and 5.0 snow leopards per 100 kID for high suitability grids. Population estimates are either expressed as the average number of snow leopard per 100 kID ^{2} or as the estimated total number within the specified area.

The suitability to density transformations were scaled using estimates derived from our radio-telemetry study site, which consituted prime habitat for snow leopards (5-10 snow leopards, excluding dependant young, per 100 kID). These numbers were derived by tracking tagged individuals and observing sign over a 4 year period (Jackson and Ahlborn 1988, Ahlborn and Jackson 1988). Elsewhere, densities have been assessed at 4 per 100 kID in the Nar-Phu

area of Nepal (Sherpa and Oli 1987) to less than 0.50 per 100 kID 2 in Xinjiang, China (Schaller

et al. 1987).

In order to explore where important corridors may exist between adjacent reserves, we developed a map showing estimated snow leopard density contours within its potential range in Nepal, using contouring software.

2.2. Minimum Viable Population Size

We used three values from the literature to define "a minimum viable population of adults "to assess the role of protected areas in supporting viable populations of snow leopard. Shaffer (1981) defined a minimum viable population (MVP) as the smallest isolated population having 99 % chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental and genetic stochasity, and natural catastrophes. Most observers are tending toward minimum population sizes of several hundred or more, rather than the widely published 50 (i.e. the so-called 50/500 rule). For the sake of simplicity, we have assumed that all adults are breeding individuals. The assumption fails to account for such social factors as the operative land tenure system, individual dominance, and age or sex-based differential reproductive potential. In snow leopard a single male could serve several females. Since male ranges overlap that of one or more females, population density may be determined more by female range size than male range size.

The three viable minimum population (MVP) values used in this study are:

1. "Short-term Survival" MVP (50 adults): Estimates in Soule and Wilcox (1980) to maintain short-term fitness (i.e., to prevent serious inbreeding and its deleterious effects) indicate the minimum effective population should be around 50 breeding individuals. Soule (1987) later termed this level "the short-term survival level", a number that applies more to animals in captivity and one that offers no guarantee against the loss of most genetic variability over time.

2. "Minimum Conservation Target" MVP (250 adults or breeding pairs): We present this figure as a more realistic target toward which planners and wildlife managers should strive. Further research may validate the need for larger population sizes, but given the lack of information for large mammals under "real-world" conditions, we suggest the figure more as a matter of convinience. At these levels, artificially manipulated breeding transfers between separate reserves is less urgent, although they are not ruled out.

3. "Optimal" MVP (500 adults): Frankel (1980) suggested that only MVP's on the order of 500 individuals are sufficient to maintain sufficient genetic variability for adaptation to changing environmental conditions. Others have suggested that the figure should be even higher, if survival probabilities are to be maintained over long periods of time (for example, Harris et al. 1987, Shaffer 1981, Soule 1987).

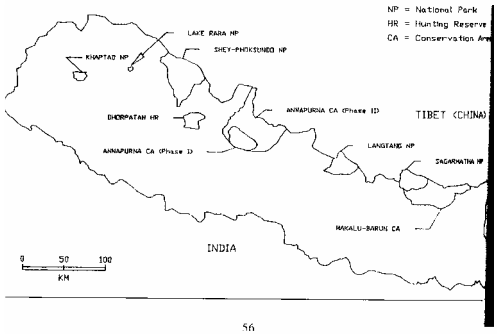
Table 2. The Existing and Proposed Mountain Protected Areas of Nepal.

Name of Protected Area	Status	Area (km2)	Location in Nepal
Existing Areas:			
Khaptad NP	Established	225	west
Lake Rara NP	Established	106	west
Shey-Phoksundo NP*	Established	3,555	west
Dhorpatan HR*	Established	1,325	west/central
Langtang NP	Established	1,710	central
Sagarmatha NP*	Established	1,148	east
	Total Existing	8,069	
Proposed or under development:			
Annapurna CA (Phase I)	Implementation	800	central
Annapurna CA Extension (Phase II)	Proposed	2,600	central
Makalu-Barun CA	Under design	2,500	east
	Total Proposed	5,900	
Total area of reserves		13,969	

Legend:

NP = National Park; HR = Hunting Reserve: CA = Conservation Area.
* = areas where snow leopards has been confirmed to occur.

FIGURE 11 EXISTING AND PROPOSED PROTECTED AREAS OF NEPAL'S MOUNTAINS



3. RESULTS

3.1. Status of Protected Areas

Until recently, there were two basic types of protected area in Nepal (HMG 1987). Firstly, national parks (NP) established by the National Parks and Wildlife Conservation Act 2029 (1973), and adminstered through the Department of National Parks and Wildlife Conservation (DNPWC), with preservation as the paramount policy. Secondly, hunting reserves (HR), where the taking of trophy animals like blue sheep *(Pseudois nayaur),* Himalayan tahr *(Hemitragus jemlahicus)* and goral *(Nemorhaedus goral)* is permitted under permit issued by DNPWC according to the National Parks and Wildlife Protection Regulations Act of 1974. There are five national parks in the Nepalese Himalaya and one hunting reserve (Table 2). Figure 1 shows the location of existing and proposed reserves which could possibly support snow leopard.

Following generally negative reactions by the local people living in or near parklands, His Majesty's Government of Nepal has begun to explore the concept of Conservation Areas (CA), whereby conservation and harmonious development is encouraged with the strong participation of the local community, and sustained through entry and user fees from tourists. The CA concept is viewed as a more flexible approach to addressing conflicts between man and wildlife, and for accommodating traditional patterns of livelihood by villagers within the park or utlizing its resources (Sherpa et al. 1986). Two CA's are being implemented or proposed. The first, the Annapurna CA Project located in the Annapurna region, is being implemented by the King Mahendra Trust for Nature Conservation (a Nepalese NGO established in 1982), with financial assistance from the World Wildlife Fund (USA). Phase I will protect an area of about 800 km which will probably be expanded to between 2,000 and 2,600 km in the future (Phase II). The second CA,the Makalu-Barun CA is under evaluation by the Department of National Parks and Wildlife Conservation, with funding fromthe Woodlands Mountain Institute of West Virginia (USA). It is projected to add about 1,500 km of alpine habitat immediately east of Sagarmatha NP.

3.2. Habitat Suitability

The habitat suitability ratings shown in Table 3 provide a relative estimate of habitat suitability for snow leopard within protected and unprotected areas. The minimum and maximum values indicate the range in suitability (by 100 km grid) for a particular reserve. The slightly higher habitat suitability within protected areas (HSI = 0.74) reflect their generally more rugged terrain and much lower density of human habitations than exists in the adjacent but unprotected lands within snow leopard range (HSI = 0.64). The mean number of villages outside protected areas exceeds 20 per 100 km , while highest village density within a large park (Langtang) is about ten or less per 100 km 2 (Table 3). These estimates also include villages located within a buffer strip some 10-25 km wide along the park's perimeter, since people from these villages could be expected to use resources within the protected area. The lower HSI ratings for Rara and Khaptad National Parks may reflect their lower elevational placement within the Himalaya, a less dissected terrain and the high level of human presence. Both are small parks, surrounded by dense human habitation and located well within the forested zone. A

Table 3. Habitat Suitability Ratings for Protected and Unprotected Areas in Nepal

	HSI Values/100 km2				Village Density	
Category	Mean	No	Min	Max	Total Nol	Mean No/100 km2
Lake Rara NP	0.42	3	0.40	0.46	32	10.67
Khaptad NP	0.42	5	0.33	0.66	94	18.80
Shey-Phoksundo NP	0.74	49	0.40	1.00	69	1.38
Dhorpatan HR	0.73	17	0.53	0.86	48	2.82
Langtang NP	0.70	23	0.40	0.93	213	9.26
Sagarmatha NP	0.72	19	0.59	0.80	60	3.16
Existing Large Protected Areas only	0.74		0.33	1.00	399	3.56
All Existing or Proposed Protected Areas	0.70		0.33	1.00	793	3.81
Unprotected Areas	0.64		0.26	0.93	3,296	20.10

NP = National Park; HR = Hunting Reserve; CA = Conservation Area.

1 also includes those villages which are located within 10 km of the reserve boundary

Table 4 Snow Leopard Population Estimates for Existing Protected Areas

Protected Area	Reserve Area (km2)	Number of Cats	Avg no Cats per 100 km2	Uniform densities of 0.51100km2	5.0/100km2
Khaptad NP	225	0.9	0.18	1.1	11.2
Lake Rara NP	106	0.6	0.20	0.5	5.3
Shey-Phoksundo NP	3,555	138.0	2.82	17.8	177.7
Dhorpatan HR	1,325	17.0	1.00	6.6	66.2
Langtang NP	1,710	56.0	2.42	8.5	85.5
Sagarmatha NP	1,148	43.5	2.29	5.7	57.1
Total	8,069	255.6		40.2	403.0

NP = National Park; HR = Hunting Reserve
Snow leopard density estimates are based on grids of 100 square kilometers in size.

sharply different situation exists in Shey-Phoksundo NP, which is known to provide prime habitat for snow leopard. This protected area has the lowest density of villages (1. 3 8 villages per 100 km) of Nepal's protected areas. Our radio-tracking study site was located in the extreme western portion of the Shey-Phoksundo NP. In general, large parks (greater than 1,000 km in extent), tended to have higher habitat suitability ratings, although values were closely distributed.

3.3. Estimated Snow Leopard Populations

Country-wide Population:

A total of 36,640 km 2 or 25.9 % of Nepal fitted the criteria as potential snow leopard range. According to HSI model, Nepal's snow leopard population is projected to total1,221 animals, with about 256 (or 21 % of the total) occurring within existing protected areas. The population of unprotected areas is estimated at just under 1,000 animals. Assuming uniform densities of 0.5 or 5.0 animals per 100 km , the county-wide population could amount to 183 and 1,832 snow leopards, respectively.

The addition of the Annapurna and Makalu-Barun conservation areas to Nepal's list of protected sites would increase the estimated number of snow leopard within reserves to 425, a 60 % increase over existing conditions. Nearly all of the additional increase accrues from the Annapurna Conservation Area (Phase I and II). These actions could raise to four the number of protected areas with snow leopard populations of more than 50 animals, or half of the country's protected areas. The reserves are the Shey-Phoksundo NP, Langtang NP, the adjacent Sagarmatha NP and Makalu-Barun CA, and the Annapurna CA. In area, these reserves could total as much as 13,969 km ,or 10% of Nepal's land area.

Existing Protected Areas:

Table 4 indicates the projected snow leopard population within Nepal's existing reserve system. According to habitat suitability estimates, only two parks (Shey-Phoksundo and Langtang) are predicted to be capable of meeting the "Short-term Survival" MVP value of 50 snow leopards, although Sagarmatha NP nearly achieves this number. The two smallest reserves, Khaptad NP and Lake Rara NP appear capable of supporting very few, if any, snow leopard. As the largest protected area, Shey-Phoksundo NP is projected to support nearly 3 times the lowest MVP value, but its population would still be well short of the intermediate MVP value of 250 snow leopards. In concert, all existing areas could possibly support that number, but estimates still fall well short of the optimal MVP goal of 500 animals (Table 4).

According to our map-based data, estimated snow leopard densities ranged from 2.8 cats per km2 in Shey-Phoksundo NP to *0.2* per 100 km in Rara and Khaptad National Parks, with an average density of about 1.5 snow leopards per km . We compared these population estimates to numbers based upon uniform density levels of *0.5* and 5.0 cats per 100 km respectively. Thus, without regard to variation in habitat quality, and assuming a high density value, only three parks

(Shey-Phoksundo, Langtang and Sagarmatha) would achieve a MVP levelof 50 snow leopards, but none would meet the MVP objective of 250 animals. An area 10,000 km in extent is required to support 50 snow leopards at a uniform density of 0.5 animals per 100 km , or three times as large as the biggest protected area.

Proposed Protected Areas:

To what extent would the situation improve if Nepal's national parks and hunting reserves were augmented by the Conservation Areas being developed or under consideration? The first phase of the Annapurna Conservation Area Project (ACAP) w°uld add another 46 snow leopards, assuming an average density of 2.4 :row leopard per 100 km . At some time in the future, ACAP would be enlarged to 2,600 km and possibly to as much as 3,800 km2. Prime snow leopard habitat along the border with Tibet in the Nar-Phu valley and other regions north of

Manang would be included within the expanded boundaries. Assuming 2,600 km is protected, this reserve's snow leopard population could amount to about 156 cats. population estimates for the proposed Makalu-Barun CA are based upon a core area of more than 1,500 km2 being added adjacent to the Sagarmatha (Everest NP). According to habitat suitability values, the total leopard population of the area would increase from about 44 to 57, a density of about 2.1 cats per 100 km . This small incremental increase is attributed to the fact that much of the additional area consists of forest or permanent snowfield, both of which are non-habitat for snow leopard. In addition, the general area supports a relatively high density of villages.

3.4. The Role of Corridors between Protected Areas

Thus far, the potential for interchange between adjacent reserves has not been addressed. We conducted a preliminary assessment of the nature of the corridors between these protected areas. The mean distance between any pair of existing reserves in Nepal's mountains is about 78 km, with the closest reserves being Shey-Phoksundo NP and Dhorpatan HR, separated by about 13 km. From these reserves in west Nepal there is a gap ofabout 230 km to the Langtang NP in central Nepal (Figure 1). Another gap of 60 km exists between this reserve and the next one to the east, Sagarmatha NP. With implementation of the Annapurna CA projectthe average distance between protected areas would be reduced to about 50 km, with the greatest gaps occurring between the Dhorpatan-Shey-Phoksundo complex and the Annapurna CA, a distance of about 45 km, and Annapurna to Langtang NP, separated by some 70 km. Four reserve clusters can be distinguished (Figure 1). In the west, there is Shey-Phoksundo NP and Dhorpatan HR (area = 4,880 km ; snow leopard population = 155). In central Nepal there are two separate clusters, Annapurna I and II (2,600 km or more; population 156) and Langtang NP (area = 1,710 km , population = 56). In east Nepal the Sagarmatha NP and Makalu-Barun CA

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FIGURE 21 ESTIMATED SNOW' LEOPARD DENSITY

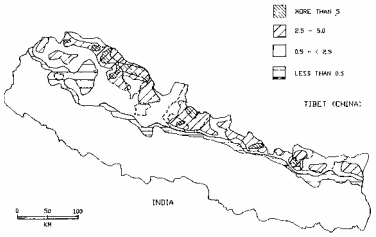

Table 5 Estimated snow leopard population size for selected national parks, reserves and proposed conservation areas.

Protected Area(s)	Q	Estimated Total Snow Leopard Population Within Varying Distances (in km) of Parks and Conservation Areasl 50	100	150	200
Existing Parks and Reserves:					
Shey-Phoksundo NP	138	189	206	242	264
Dhorpatan HR	17	32	41	48	65
Langtang NP	56	76	81	88	97
Sagarmatha NP	43	77	84	102	110
Proposed Conservation Areas:					
Annapurna I CA	46	65	77	99	117
(Phases I and II)	156	187	213	228	247
Makalu-Barun CA2	57	104	111	132	145

1/ Snow leopard numbers within buffers of varying distance from each park are based on circles of increasing size, and thus which include other protected populations as the width of the buffered zone increases to include more reserves (see text).

21 Includes snow leopard population of adjacent Sagarmatha NP (see text).

cluster totals about 3,000 km2 and supports an estimated 57 snow leopards.

Another way of viewing the area between reserves is to estimate populations within varying width buffer zones of each reserve. Table 5 shows the cumulative projected snow leopard population size within selected distances from the larger protected areas. If projected areas are considered in isolation to one another, only Shey-Phoksundo NP (existing) and Annapurna II CA (proposed) appear capable of meeting the MVP goal of 250 animals within some 200 km of their respective boundaries. Considerably more snow leopard habitat exists within 100 km of Shey-Phoksundo NP than within the same distance of Langtang or Sagarmatha National Parks, even if one were to include cats residing within the neighbouring parts of Tibet. If populations of all protected areas were summed, a MVP goal of 500 individuals could be achieved within 100 km of existing reserve boundaries or within 50 km of existing and proposed protected areas (Table 5). Whether sufficient exchange of genes would occur between the four widely separated reserve clusters, without invention by man, it is not known since no data exists on dispersal rates in snow leopard.

An examination of estimated snow leopard density contours within its potential range in Nepal indicates the snow leopard range tends to be narrow and linear except in the west or far west of the country. Figure 2 suggests that the most extensive areas of high snow leopard density occur in Dolpo, Mugu, and the Humla districts, particularly along the Tibetan border. Shey-Phoksundo NP and the surrounding area is the most extensive area of high-quality snow leopard habitat. Other high density zones coincided with areas known (e.g., Nar-Phu valleys) or suspected (e.g., Langtang NP) to provide quality snow leopard habitat. The contours tend to support the idea that unprotected areas are important to achieving MVP's of 250 and 500 snow leopards respectively.

The continuity of snow leopard range is broken by deep river valleys that permit subtropical or lower temperate forests to penetrate into or near Tibet, such as the Arun or the Bhote Kosi rivers. Densely settled areas represent another potential barrier to the free movement of snow leopard (Figure 3). Contours of high snow leopard numbers seem to coincide closely with the zones of, lower village density (less than 4 villages per 100 km). Bands of higher village density extend along the Kali-Ghandaki, Trisuli, Bhote-Kosi and Arun rivers, possibly further strengthening these as barriers to movement. It is likely the mountains along the Nepal-Tibetan border playa significant role in permitting east-west movement of snow leopard and other high mountain ungulates. As indicated earlier, population projections could not be developed for the border region due to the lack of topographic maps. Such corridors could contribute significantly to snow leopard numbers and genetic interchange.

4. DISCUSSION

The following observations are drawn from the population distribution model presented in this paper:

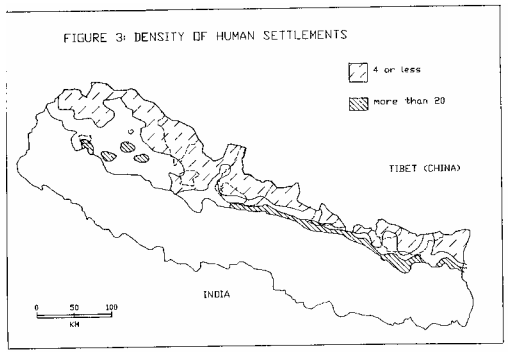
FIGURE 3: DENSITY OF HUMAN SETTLEMENTS
4 or less
more than 20
TIBET (CHINA)
INDIA
0 50 100
KM

Only four existing or proposed reserves (Shey-Phoksundo NP, Annapurna CA, Langtang NP and Sagarmatha NP) are potentially capable of meeting the MVP level of 50 individuals.

* No existing or proposed reserve would support more than 156 snow leopards within its boundaries.

* Even assuming the best case uniform density scenario (i.e., five snow leopards per 100 km^2), no existing or proposed reserve meets the MVP population level of 250 snow leopards.

* While the mean distance between any two reserves is less than 100 km, the closest cluster of existing reserves (Shey-Phoksundo-Dhorpatan and Langtang) able to support a combined population of 250 snow leopards are separated by a distance of 230 km. With implementation of the Annapurna Conservation Area (Phase II), this will be reduced to about 45 km.

* Sixty-five percent of the snow leopard population projected by this model is located outside the boundaries of existing or proposed protected areas. Unprotected habitat is critical to meeting MVP's of 250 and 500 snow leopards.

The HSI model can be criticized in several respects. First, it has not been tested or adequately validated in the field; second, the area from which estimates of suitability were made could encompass the home ranges of 10 or more snow leopards, according to a recent study (Jackson and Ahlborn 1989); and fmally, the derived HSI value is map-based and is not necessarily accurate. Therefore, populationestimates were also based on uniform snow leopard densities of 0.5 and 5.0 animals per 100 km^2. These data indicate that the existing network of reserves would not support 500 snow leopards, even given the best case scenario. Even at moderately high densities, minimum viable populations of snow leopard in Nepal cannot be supported by protected areas alone. High snow leopard densities are probably only maintained in isolated valleys with broken terrain and good blue sheep populations (Jackson and Ahlborn 1989, Sherpa and Oli 1987).

While the carrying capacity of snow leopard in some parks (for example Shey-Phoksundo) is high, all Nepalese protected areas, like those of other Himalayan countries tend to be small: none approaches 10,000 km^2 in size or the scale of reserves found in the sparsely populated parts of China (Qinghai), the Tibetan Autonomous Region, and Mongolia. Criteria regarding the

minimum size of protected areas for snow leopard have not been developed. Even at the high

densities, overlapping ranges and small home range sizes (12 - 39 km^2) observed in favourable

habitat (Jackson and Ahlborn 1989), areas well in excess of 500 km^2 would be needed to maintain a population of at least 50 breeding individuals with inbreeding at less than 1 % (Frankel and Soule 1981).

The assumption that parks represent the only islands of "suitable habitat" in a sea of "unsuitable habitat" does not necessarily hold for the Himalayan mountain region. Most protected areas have one or more permanent settlements within their border and people from outside also bring their animals to graze within the refuge. While national parks contain

fewer villages than the surrounding area, the local community may exert considerable pressure upon alpine pastures within the park. Although large ungulates are usually better protected within a park, their habitat may be as overgrazed by livestock or as poorly managed as unprotected alpine pastures. Thus livestock grazing, fuelwood collection and burning may be pervasive environmental modifiers of plant succession and composition, whether the area has been designated a park or not.

Besides village density, the main difference between many protected and unprotected areas rests with hunting pressures upon predator and prey populations, which tend to be much greater outside of protected sites. Although large predators are better protected within parks, shepherds using protected area high-altitude summer pastures usually take matters into their own hands and attempt to kill persistent depredators, whether the park authorities take action or not.

As native ungulate populations are depleted, so large predators are increasingly forced to subsist upon domestic stock. The potential for conflict is high, since livestock are usually grazed in the same pastures as the native prey species. Any persistent attempt by snow leopard to subsist upon domestic stock results in retributive measures, and unless protected by village edict or religion, the animal responsible is not likely to survive for long. In some areas depredation losses may cause significant economic hardship and thereby engender considerable antagonism toward snow leopard as well as other large predators (Schaller et aI. 1987, Sherpa and Oli 1987). Given these factors, it is hardly surprising that some of the best protection exists in areas which are isolated from human activity by geographical or topographical factors, or in areas where people are less dependant upon animal husbandry and thus more tolerant of livestock losses.

The model suggests that unprotected areas will continue to harbor a large proportion of Nepal's snow leopard population, unless the size of its mountain parks are increased dramatically. Given the generally negative manner in which local residents and politicians view national parks, attempts to expand the network in the traditional way would meet with considerable social and political opposition. More than 7 percent of the country is already in national park status. An alternative option involves the maintenance of gene flow through periodic translocations of animals or through semen and embryo transfers. These techniques have not been proven, and are too far from reality to be considered as a viable scenario for the Himalayan region.

A preferable strategy involves attempts to meet MVP numbers by managing and protecting snow leopards within protected as well as unprotected lands. This will necessitate surveys to identify potential corridors between reserves with the greatest capability to support snow leopard, to delineate those areas that best meet the needs of snow leopard, and to eliminate from further consideration areas where conflicts with humans are likely to be significant. The best option appears to be corridor linkages between the Shey-Phoksundo, Dhorpatan and Annapurna protected areas. Measures should be implemented to better ensure protection of the natural prey base and to minimize the susceptibility of livestock to depredation. Protection of native

prey species would greatly benefit snow leopard: by ensuring populations of blue sheep, Himalayan tahr or goral are not over-exploited, local communities can assure themselves and snoW leopards of a sustainable food supply. Such wildlife may benefit the growing tourist industry, and thereby the local economy. Many of Nepal's rangelands are under substantial pressure from too many animals being grazed too often and intensively. Changes in grazing routines, ensuring the herds are guarded or returned to safe corrals at night, encouraging large bovids like yak rather than vulnerable species like sheep or goats, and better methods of forage collection, could minimize conflict. In some cases, compensation for livestock losses may be warranted, but a preferable strategy would be to provide incentives for good livestock management practices.

The purpose of connecting selected reserves with "corridors" is to encourage regular dispersal and subsequent genetic exchange between otherwise isolated protected area populations. Like tigers and other large solitary felids, a segment of the snow leopard population may be transient non-breeders, searching for vacant home range in which to establish themselves. No data is available on dispersal patterns of snow leopard, but tigers in Nepal's lowlands dispersed as much as 66 kID (C. David Smith, pers. comm.). The distance three radio-tagged leopards dispersed in the same area was considerably less (Sunquist 1983).

Habitat fragmentation and poaching were cited as the primary factors behind tiger population declines, and many reserves were small and isolated (Seidensticker 1980). Simberloff and Cox (1987) discussed the value of corridors to the Florida panther, noting that "inbreeding could possibly be stemmed somewhat by a corridor system", but concluding that its cost could be excessive given the amount of habitat fragmentation and development that has occurred in the region. Fortunately, changes in snow leopard habitat in the Himalaya are less pervasive, given subsistence economies and the greater dependance of people upon animal husbandry and natural pastures.

5, CONCLUSIONS

There appears to be widespread agreement that large reserves are needed to minimize extinction rates, to sustain widely-ranging species, and to protect over the long-term species whose density is low. Most conservation biologists support the notion that large areas are needed to preserve entire ecological communities intact, suggesting that the larger a reserve is the better it is buffered from outside disruption (for example, see Simberloff 1986 and Blouin and Connor 1985).

As noted above, virtually all Himalayan reserves are intensively used by man for grazing his livestock or for the collection of fuelwood, fodder and medical plants. In order to better ensure minimum viable populations of species like snow leopard, we urge that much more attention be devoted to managing wildlife habitat and populations in the intervening areas between selected sets of reserves, around the perimeters of existing reserves, and in areas judged marginal for agriculture due to steep slopes or poor soils, or in areas supporting few humans. The best way to engender a conservation ethic is to improve the standard of living of

the people who share the land with wildlife.

For the endangered snow leopard, such actions are best focussed on maintaining habitat quality through improved livestock management, the reduction of hunting and the promotion of income-generating jobs. The "Conservation Area" concept is an innovative attempt at meeting these needs. It involves the local communities more closely in decision-making issues involving land management issues, and places emphasis upon improving their standard of living through sustainable tourism, cottage industries, handicrafts, or other income-generating activities. If the needs of wildlife and man can be successfully intergrated, CA's could
support a relatively large proportion of Nepal's protected area snow leopard population. Policies developed in these experiments could also applied to selected buffer areas or corridors, to permit exchange between key protected areas to occur naturally. Since habitat within Tibet (China) is also important to Nepal's leopard population, international co-operation in the management of snow leopard is warranted. The recently declared 35,000 km 2 Qomolangma Nature Preserve, which connects Langtang and Sagarmatha National Parks along the Tibet (Chinese) side of the border, is a prime example of a reserve beneficial to both countries.

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